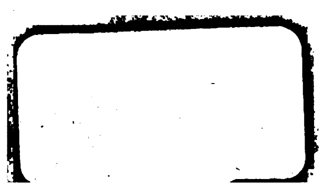

FRONTISPIECE.

Foot of Spider, × 150.

PRACTICAL

Photo-Micrography:

BY THE LATEST METHODS,

BY

ANDREW PRINGLE, F.R.M.S.,

President of the Photographic Convention of the United Kingdom, 1889. Joint-Author of "Processes of Pure Photography," etc., etc.

NEW YORK:
THE SCOVILL & ADAMS COMPANY.
1890.

TO THE MEDICAL PROFESSION.

THIS BOOK, PARTLY INTENDED TO PROMOTE

PHYSIOLOGICAL RESEARCH

BY PHOTOGRAPHIC METHODS,

IS DEDICATED.

PREFACE.

No apology seems to be necessary for this book. So far as I know, no attempt has been made by any person apparently up in the subject to give instructions for Photo-micrography, since time has elapsed for proper trials of the two great and novel features of the Science, Apochromatic Objectives and Color-correct Plates. My experience, though limited in duration, has been gained by assiduity and very varied practice, and the whole, practically, of my study has been directed to the investigation and utilization of our two new tools above named.

I have written deliberately and confessedly for the Natural and Medical Sciences rather than for those who use the microscope as a pastime. But I have not overlooked the intelligent investigators of such subjects as diatom-structure and the like; for in objects whose real structure is so problematic lies not only a valuable field for optical research, but much of the future of practical optics, and perhaps the very best *manège* for the student photo-micrographer. I boast, however, to have written something that will materially help those who study the Natural Sciences in general rather than Optical Science in particular.

I have to thank many friends for help of various kinds. Mr. Edward M. Nelson, my instructor in practical microscopy, has placed me under the most marked obligation, for he kindly read my M.S. so far as it touched optical theories, and he directed me where necessary. I owe so much generally to

Dr. R. L. Maddox that I need not particularize any late favors. I thank certain opticians for blocks which appear in these pages, notably Mr. Powell, Mr. Swift, Mr. Beck, Mr. Baker, and Mr. Newton.

Apology is perhaps due for over frequent reference to a book in the writing of which I took part. It seemed better to refer even to my own writings than to waste space in the present book.

Andrew Pringle.

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PLATES.

FRONTISPIECE.

FOOT OF SPIDER, × 150.

Color of object—Brown-yellow.
Screen used—Pale yellow.

Objective—16 mm. apochromatic.
Ocular—Projection No. 8.
Condenser—Lower part of achro. by Swift.
Light—Lime.
Plate—Landscape gel. brom.
Exposure—5 minutes.
Development—Pyro ammonia.

PLATE I.

1.

HAIRS ON PROBOSCIS OF BLOWFLY. Critical image, × 875.

Color of image—Brown.
Screen—None.

Objective—6 mm. apochromatic, N. A. ·95, Zeiss.
Ocular—Projection No. 8.
Condenser—Achromatic 140 deg.
Light—Lime.
Plate—Lantern-slide gel. brom.
Exposure—2 minutes.
Development—Pyro ammonia.

2.

INJECTED VILLI, INTESTINE OF RABBIT, × 30. Preparation by E. C. Bousfield, L.R.C.P.

Color—Very dense orange-yellow.
Screen—None.

Objective—Swift 1 inch.
Ocular—None.
Condenser—Lower part of achro. with author's ground glass (see p. 71).
Plate—Eosin.—Light-Lime.
Exposure—14 minutes.
Development—Pyro ammonia.

Plate II.

1.

A. Margaritaceus, × 150. General appearance.

Objective—16 mm. apo. at N.A. ·80.
Ocular—Projection No. 3.
Condenser—Lower part of achro.
Light—Lime.
Plate—Thickly coated landscape.
Exposure—40 seconds.
Development—Pyro ammonia.

2.

Triceratium. Critical image of secondary structure, × 750.

Objective—3 mm. apo. at N.A. 1.
Ocular—Projection No. 8.
Condenser—Powell and Lealand used dry.
Light—Lime.
Plate—Thickly coated landscape.
Exposure—45 seconds.
Development—Pyro ammonia.

Plate III.

1.

"Taste-buds" in Tongue. × 100. Preparation by E. Klein, M.D., F.R.S.

Stain—Logwood.
Screen—Pale yellow.

Objective—24 mm. apo. Zeiss.
Ocular—Projection No. 3.
Condenser—Achro. lower part, with author's ground glass.
Light—Lime.
Plate—Eosin.
Exposure—15 seconds.
Development—Pyro ammonia.

2.

Typhoid bacilli in Intestine. × 750. Preparation from the Resea.ch Laboratory, Royal College of Physicians, Edinburgh.

Stain—Gentian violet.
Screen—Medium yellow.

Objective—3 mm. apo. at about N.A. 1.
Ocular—Projection No. 3.
Condenser—Zeiss. Apo. N.A. 1.
Light—Lime.
Plate—Eosin.
Exposure—90 seconds.
Development—Quinol-caustic.

Plate IV.

1.

B. ANTHRACIS IN BLOOD. × 750. Preparation by W. T. Wilson, V.S

Stain—Deep gentian violet.
Screen—Medium yellow.

Objective—3 mm. apo.
Ocular—Projection No. 3.
Condenser—Achro. at about 140 deg.
Light—Lime.
Plate—azaline stained.
Exposure—35 seconds.
Development—Pyro ammonia.

2.

SPERMATOZOA OF TRITON, × 1000. Preparation by G. F. Dowdeswell.

Stain—Fuchsine.
Screens—1 pale, 1 dark, yellow.

Objective—2 mm. apo.
Ocular—Projection 3.
Condenser—Achro. 140 deg.
Light—Lime.
Plate—Eosin.
Exposure—About 2 minutes.
Development—Pyro ammonia.

Plate V.

1.

"PNEUMOCOCCI," ENCAPSULED. × 500.

Stain—Fuchsine-deep.
Screen—None.

Objective—$\frac{1}{12}$ oil. Swift.
Ocular—none.
Condenser—Achromatic 140 deg.
Light—Oil lamp.
Plate—Ordinary rapid,
Exposure—about 9 minutes.
Development—Pyro ammonia.

2.

FLAGELLATED SPIRILLA (? SERPENS) × 800. Preparation by R. L. Maddox, M.D.

Unstained.
Screen—Medium yellow.

Objective—3 mm. apo.
Ocular—Projection No. 3.
Condenser—Acromatic.
Light—Lime.
Plate—Landscape.
Exposure—2½ minutes.
Development—Pyro ammonia.

Plate VI.

1.

Bacilli Tuberculosis in Lung of Horse. × 750. Preparation by W. Watson Cheyne, F.R.C.S.

Stains—Bacilli-red.
Tissues—Pale-blue and yellow.
Screen—Deep yellow.

Objective—3 mm. apo. used at N.A. 1.
Ocular—Projection No. 3.
Condenser—Powell and Lealand, used dry.
Light—Lime.
Plate—"Isochromatic."
Exposure—2½ minutes.
Development—Q u i n o l (hydroquinone) and caustic soda.

2.

B. Tuberculosis by Inoculation. Lung of Rabbit. × 600. Preparation by E. Klein, M.D., F.R.S.

Stain—Red and blue.
Screen—Medium yellow.

Objective—3 mm. apo.
Ocular—Projection No. 3.
Condenser—N. A. I.
Light—Lime.
Plate—Eosin.
Exposure—½ minute.
Development—Quinol caustic.

The reader is requested to note that these illustrations are given not as perfect specimens of work, nor as the best that have been produced by the author; they are given to illustrate various types of subjects and varied treatment.

Fig. 2 of Plate VI. is not a good representation of the original negative.

Practical Photo-Micrography.

CHAPTER I.

INTRODUCTORY AND HISTORICAL.

It would be out of place and inconvenient for the writer here to enter into any elaborate apology for the Science of Photo-micrography, or to occupy useful space with a lengthy discourse on the reasons that led him to make a study of the Science. Any one of a scientific turn of mind, and especially one who has more or less mastered the science of Photography, could not, on entering the microscopic world, fail to realize how great a boon Photography might become to microscopy, if the photographer were a good microscopist and the microscopist a skilled photographer. Should the world ever possess in one man a skilled and careful microscopist and an experienced and versatile photographer, a very great step may be expected not only towards solutions of many present enigmas and towards future discoveries, but also towards a very satisfactory and very convincing medium for publishing and certifying the solutions and discoveries.

The potential value of Photography in this line has always been admitted and often dwelt upon; but difficulties, some real, some exaggerated, some imaginary, have always been cited as fatal to the employment of Photography for the delineation

by a graphic method of microscopic images. That difficulties, and often great ones, present themselves is matter of fact, but to smooth over some of these difficulties, to evade some and to conquer others, it is the writer's ambition to assist the reader.

Two classes of photo-micrographer are met with in the ordinary course; the first a microscopist of more or less experience and skill, who suddenly bethinks himself that photography seems an easy and rapid way of graphically representing his objects and his observations; he never doubts that he may in a very short time master the elementary troubles of photography, and accordingly he embarks in a cockle-shell on the most stormy waves of a great and growing science. The other class of photo-micrographer is the photographer, usually the amateur, who thinks he has conquered the realms of landscape and portraiture, and sighs only for fresh conquests; and so he plunges blindly into the science which of all others requires practice, perseverence and acute powers of observation. The results are shame and calamity to photo-micrography as a utility, as an educator, as a science. Photo-micrography has not yet taken the place it deserves, demands, and shall finally take. It is much to be regretted, but it is true, that we have so many books on photo-micrography written by men who are only smatterers in microscopy and totally ignorant of anything but the very rudiments of photography. Much has been well written on the subject, but the science is advancing so rapidly that what was in the front one week is "exploded" and improved out of knowledge the next week.

Even were it desirable, our space makes it impossible, to enter at any length on the history of photo-micrography. Some assign the credit of the first photo-micrograph to one person, some to another; but we confine ourselves to saying that among the earliest workers in this line were Wedgewood, Rev. J. B. Reade (about 1837), Mr. Dancer (1840), Mons. Donné (1840), Mr. Archer (1851), etc. Among the early workers was Dr. R. L. Maddox, admittedly the suggestor of gelatine emulsion for photography, and still alive to view the results of his own work and talents, and to lend a helping hand and

give valuable instruction to beginners as he most generously did to the writer. No man has worked more perseveringly or more successfully in this branch of science than Dr. Maddox, and no man ever got less reward—beyond that of conscious merit—than our good friend. His photographs of *Pleurosigma angulatum* × 3,000, of many micro-organisms, and of various other subjects still rank among the best works that have been produced.

The work of Dr. Woodward of the U. S. Army was so remarkable and so excellent as to mark, or even to *make*, an era of itself. This scientist was a microscopist of the very foremost rank, a generous government placed at his disposal the very best instruments, and the results amply justified the country's confidence, for Dr. Woodward's photo-micrographs of *Amphipleura pellucida*, of Nobert's test plates, of the well-known test "*Podura* scales," as well as of many physiological and pathological subjects have seldom if ever been equalled. If these works of Dr. Woodward's are ever beaten the superiority will be due to late improvements in optical appliances, and to the use of more sensitive "color-correct" plates for photography.

Dr. Koch, the eminent authority on micro-organisms, has produced fine photographs of bacteria, and Dr. E. M. Crookshank, Professor of Bacteriology at King's College, London, has published not only a number of photographs of Bacteria but also, in a succinct and ably written book, his methods of producing his photographs with capital diagrams of his apparatus.*

The Diatomaceæ, as might be expected from their beauty, have always been favorites with the photo-micrographer, but from their formation they have always proved severe tests for the powers of those who have attempted them. Besides the micrographs of Dr. Woodward we must notice some very fine work by Dr. Mercer, also an American citizen. Drs. Abercrombie and Wilson in England were very successful in photographing the diatomaceæ, and lately Messrs. A. Truan y Luard

* Photography of Bacteria, by Edgar M. Crookshank, M. B., F. R. M. S. London: H. K. Lewis. 1887.

and Otto N. Witt, the former of Spain, the latter of Prussia, have succeeded in producing a magnificent set of photographs of the Diatomaceæ of Hayti, West Indies. These collaborateurs found that they obtained the best results, or rather the only good results, by using the wet collodion process. The writer, while inclined to traverse this assertion of the superiority of wet collodion over suitable gelatine emulsion, will have occasion to advert to the *modus operandi* of these undoubtedly skillful and successful workers in a later part of this book. Dr. R. Zeiss, of Jena, has lately exhibited certain photographs of *A. Pellucida* and *P. Angulatum*, which in Britain excited considerable comment of a highly favorable kind. The late Isaac H. Jennings produced some very creditable photographs of diatoms, notably one of *N. Lyra;* and his treatise on Photo-micrography is one of the best in the English language, though late optical and photographic advances have made the book a little out of date.* Another work worthy of perusal, on account of the careful treatment in brief space of the optical part of the subject, is that by Dr. E. C. Bousfield, who is not only an adept with the microscope but has been highly successful in the department of photo-micrography.†

Still confining himself to work that he has seen, the writer would now draw attention to the magnificent "critical image-photographs" of Mr. E. M. Nelson, of London. A microscopist of long and varied practice, of consummate skill, and possessed of an intimate knowledge of microscopic optics, Mr. Nelson has laid himself out for the most difficult branches of photo-micrography, the photography of the highest possible resolutions of such subjects as muscle-fibrils, "secondary structure" of the diatomaceæ, and ordinary diatom structure of the most delicate kind. To Mr. Nelson the writer owes practically all the knowledge he has of microscope-manipulation, and to Mr. Nelson's unstinted instruction and careful explanations the writer is indebted for any measure of success he has

* Photo-micrography; or, How to Photograph Microscopic Objects. By I. H. Jennings. London: Piper & Carter. 1886.

† Guide to the Science of Photo-micrography. By Edward C. Bousfield, L. R. C. P. London: W. Kent & Co. 1887.

had in this branch of science; not forgetting the unwearying kindness of Dr. Maddox when the writer was an entire novice in everything microscopic.

A great many other names would have to be mentioned did this chapter profess to be a history of the science with which we are dealing. Drs. Draper and Sternberg of America have done more than "Yeoman Service" in this line; Mr. Wenham, Mr. T. Charters White, Mr. Shadbolt, Dr. Lionel Beale in England; in France Dr. Miquel and others; in Italy Count Abbé Castracane; and Neyt in Bèlgium—all have made their marks in photo-micrography. Dr. Heneage Gibbes, now Professor of Physiology in Michigan, and Mr. F. H. Evans, of London, have produced some useful photographs of physiological preparations. So of late years have many other persons, for the value of photography in this line is daily attracting more and more attention. It appears to the writer that for the instruction of a class of students in such branches as histology, physiology, pathology, bacteriology, etc., no method can equal the use of an Optical-lantern slide projected upon a screen, the room being temporarily darkened; there are no such difficulties or inconveniences as would at first sight appear, and a chapter of this book shall be devoted to the subject, in the hope that attention may be called to this very scientific and convenient means of imparting instruction.

A few words may aptly be written on what the writer claims as the advantages of photo-micrography over other existing methods of delineation. In the first place, "Personal Equation," or perhaps "Personal Prejudice," is almost entirely eliminated. A dishonest man may possibly arrange his photography so as to bear out his own previous assertions, but a candid person doing his best to secure truth will be confident that what his photograph shows represents what his lens "saw," and those who see his photograph will know that it represents the object in one aspect at least. The aspect may be a delusive one through optical mismanagement, but it must be one aspect of the object. Photography certainly cannot lie, but the photographer may be a liar or a fool. For this reason the photo-micrographer must not only be unprejudiced and honest, he must also be a microscopist and know his object.

Many microscopic objects are so fine in substance, others so intricate in structure, that the human hand is unable by any device to draw them anything like accurately. No line visible to the naked eye is too fine for photography to limn, no structure too intricate for the pencil of light to follow.

By photo-micrography a vast amount of time is saved. A few minutes of work may furnish us with a matrix for a thousand prints, one of which, if possible at all, could not be produced by hand in many hours. By photography are done with moderate ease and complete accuracy many subjects which by hand could not be done at all, witness moving objects, and appearances rapidly changing.

Many other claims might be made for photo-micrography, but we shall cite only one more. Of all the intellectual and scientific pursuits that can be named, no one possesses so great, so varied fascinations as photo-micrography. There is mental food and mental exercises for every one; microscopy in all its varied branches and with all its interests—optics, mechanics, chemistry; and best of all, a practical, visible, permanent, useful result—an education and an educator!

NOTE.—Since the above was written, Drs. Fraenkel and Pfeiffer, of Berlin, have begun to publish a set of photo-micrographs of bacteria which may be called splendid. They use daylight, apochromatic lenses and orthochromatic plates.

CHAPTER II.

PREPARATIONS FOR WORK.

A GREAT deal of time, trouble and expense will be saved by a careful consideration of certain matters before any attempt is made at actual work. It is probable that after actual work has been carried on for some time alterations may be found necessary and improvements may suggest themselves; but the earlier lessons of practice and experience will be well nigh wasted if there is not in the first arrangements a certain amount of forethought and fore-knowledge. We shall here, therefore, endeavor to smoothe the way for the beginner by giving hints, as close as possible to directions, on such matters as apartments, and apparatus of a general nature, leaving a more detailed description of special apparatus for future chapters.

A great advantage will arise from having two apartments communicating with each other for the two branches of the work: the microscopic or exposure work, and the photographic or development work. If two communicating apartments are not available, two adjacent ones may do almost as well; or with certain evident precautions one chamber may be used for both lines of operation. Wherever the apartment for making the exposure may be, it is of the utmost importance that it be steady; with a good sound floor, and as far as possible removed from house or street traffic. No place is usually so suitable as a basement or half-basement cellar, and if this ground apartment have floor and walls of cement, and a strong ceiling, it will probably be *perfectly* adapted for the work. But even such an apartment should be as far as possible distant from street traffic, if the finest photo-micrographic work is intended. Mr. E. M. Nelson, alluded to in last chapter, works in a cellar such as just described, using for his apparatus a base not only itself very heavy but further weighted with several hundred-

weight of lead, yet he never attempts his most critical work till after 9 P. M., though he does not live in a very busy thoroughfare but in a quiet suburb of London. The writer, too, works in a cement-floored and walled half-basement in a very quiet village, but has had negatives spoiled by the tremor of a passing 'bus or of a heavy step overhead. There should be no chance, therefore, of vibration or tremor in any part of the apparatus or apartment. And further, the whole of the apparatus actually used to produce a negative—the light, the condenser-system, the microscope, the camera and the plateholder—should all, during exposure at least, be practically one solid mass; in other words, the whole system must be firmly clamped to one base, and that base should be the floor if possible. The entire system being clamped to one base, even if that base be not itself above suspicion, moving, all other parts move in unison, so that blurring may be avoided; we have heard of a plan by no means bad, wherein the whole system on a strong base was suspended by cords from a high support. If strong India-rubber formed part of the length of these cords the apparatus was probably very satisfactory, and the idea was surely ingenious. India-rubber cubes have often been found very beneficial as supports for the base-board of a system where tremor is inevitable.

If by any chance the illuminant to be used is daylight, whether diffused or direct sunlight, this consideration must naturally play an important part in the selection of an apartment. If daylight is to be used for the development of the photographic plates, a course which we do not recommend, it is almost essential that the window of the room chosen face the North. The writer has but little experience of daylight as the illuminant for making the exposure in the camera, but where daylight, and especially sunlight, can be depended on, it is perhaps the best of all illuminating agents. In Britain we believe it impossible to obtain anything like uniform results, though no doubt at odd times great successes may be, and have been, scored by sunlight. Now that photographic emulsions are made so sensitive to actinic light, the great advantage of sunlight is of less consideration, while the superior

equability of artificial light makes it a far more certain factor in our work than ever daylight could be, even at its best and steadiest. The fact that some magnificent work—as of Drs. Woodward, Maddox and others—has been produced by daylight only leads us to regret that these eminent workers had not the advantages we have of equable radiants and very sensitive plates. There are, however, over and above the actinic value of daylight, certain qualities in daylight that make it, in spite of its inferiority in some respects, invaluable if not essential for certain kinds of work, and we do not wish to be taken as despising or rejecting daylight entirely as our radiant. No treatise on this subject would be complete without more than a passing allusion to the use of natural light as the radiant, and accordingly the subject shall be treated in such manner as is within our power.

Another advantage worthy of note, though always overlooked, pertaining to basement apartments, is the equability of temperature. The writer's half-basement operating rooms do not vary 10 deg. Fahr. in the course of the entire year; never unbearably cold in winter they are a refreshing change from the outside heat of summer. This is of more importance to the advanced photo-micrographer than might appear; the microscopic apparatus keeps better and works better in such conditions, and in such a room, in cold weather especially. The heat arising from the radiant of whatever kind it be, produces much less serious effects on the apparatus, and much less time is required for the parts to "settle" into their places. (See p. 173.)

The above remarks are intended for those who propose to enter seriously into the work of photo-micrography. Those who propose only to work at odd times or on the easier subjects, will not require such perfect preparations, or such perfectly adapted apartments; it will be well, however, for every intending worker to keep our hints in mind and to choose apartments as nearly as possible fulfilling our *desiderata*.

The purely photographic exigencies of the work may be met either completely or partially according to the means and intentions of the worker. Development of a micrographic

negative is a matter requiring most accurate visual observation, and that by a non-actinic light; the light in question must therefore be equable, ample, and "safe." Running water is so great a convenience that many other desirables should, if necessary, be sacrificed for a supply of water from a tap; for this reason, and also by reason of the waste-pipe, we might prefer a room otherwise inconvenient if furnished with a tap, sink and waste-pipe, to an apartment in other respects more comfortable and convenient.

Critical photo-micrography requires at every stage complete concentration of thought. The worker must not be distracted in the very slightest degree while "setting up" his object or while developing his negatives. All steps, therefore, should be taken to avoid confusion in the rooms of work. The fewer the bottles of chemicals in the dark room, and the more neatly they are arranged the better; presses and shelves should be provided for everthing required, which luckily is not much unless great digressions are to be made from the matter treated of in this book.

Very good work may be done with apparatus of ordinary quality, but the very best work will only be done, and can only be expected to be done, by the very best apparatus used with the utmost skill. We therefore counsel our Reader to begin with the best of everything, so far as he can afford to procure it. It is false economy to buy mediocre instruments for a start, because if we succeed and persevere we are sure to require better implements as we advance in skill; while if we fail, become disheartened, and "chuck the thing up," our shoddy outfit is valueless.

It is difficult to draw a line between "easy" and "difficult" photo-micrography, because each branch has its own difficulties. In low-power work which is often called "easy" we have to meet difficulties of uneven illumination, uneven surfaces and puzzling colors; in high-power or wide angle work, we have to contend with difficulties in optics, in vibration, and in photographic technique. But always the best instruments produce the best work, though often the best instruments are the most difficult to work to their best advantage.

If it is true, and we assert that it is so, that the first necessity is a knowledge of the use of the microscope on our special object, it is no less true that he who begins photo-micrography without considerable experience in photography will have a hard task and many failures. The writer ventures to assert that an enormous deal of trouble and perplexity will be spared to the tyro photo-micrographer if he practise carefully beforehand ordinary photography, specially of varied subjects, as Landscape, Interior, Portrait, and most of all, Reproduction of *colored* objects, as Paintings. The greatest stress will in this book be put on color-correct, or "Ortho-Chromatic" photography, because the writer is well assured that not only has color-correct photography brought about vast improvements of late in photo-micrography, but that color-correct photography is destined to be the means of placing our science in the position which it claims, and will sooner or later hold as *the* means for the delineation of microscopic images. In a book of Pure Photography, wherein the present author had the advantage of collaboration with Professor W. K. Burton, C. E., the writers have pointed out with considerable clearness the effect of variations in Exposure and Development in ordinary photography, and the Reader is strongly recommended to study this book, and to gain as much proficiency as possible in pure photography before starting on the special, but varied, operations required to produce good micrographic negatives and prints.* The present book will, however, treat photography on the supposition of total ignorance on the Reader's part. The same course cannot be followed regarding the microscopic branch of the subject, for this matter is one of experience and long and close observation rather than one which can, by however much writing, be imparted from writer to reader.

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* The Processes of Pure Photography, by W. K. Burton, C.E,. and Andrew Pringle, F.R.M.S. New York, The Scovill and Adams Co., 1888.

CHAPTER III.

OPTICAL APPARATUS.

Most of our readers are pretty sure to possess a microscope, some objectives, eye-pieces, a substage condenser and a bull's-eye. (Note: The term condenser shall hereafter be used as applying solely to the "substage condenser;" while "bull's-eye" shall be used to cover all condensing or parallelizing instruments used between condenser and light). Some kind of so-called microscopic lamp is also likely to form part of the outfit. As a rule a microscopic lamp not made specially for microscopy is for various reasons unsuited to our purpose. Such adjuncts to a microscope as a Polariser, a Paraboloid, a Spot lens or other arrangement for "black ground illumination" shall be treated separately; till further notice we shall treat of *axial transmitted* light illumination only.

The Microscope. The qualities essential to a microscope-stand for our purpose are perfect rigidity, accurate working of all parts, specially racks, fine adjustments, stage mechanism, and draw tubes, if any are to be used. The substage arrangements as to focusing and centering are just as important as the other parts of the instrument. The writer proposes to lay great stress on the accurate use of the condenser, which is often treated in a careless and ignorant way, and sometimes even by certain authorities omitted altogether. When the functions of a condenser properly used are explained, it will be seen how serious an omission this is. All the best photo-micrographic apparatus we have ever seen, and all of which we have seen illustrations that gave any promise of excellence, have been used on the horizontal; on the other hand there are cases where the vertical position of the apparatus, *i. e.*, the horizontal position of the stage, is necessary. No microscope-stand will meet both conditions unless it swing on a pivot,

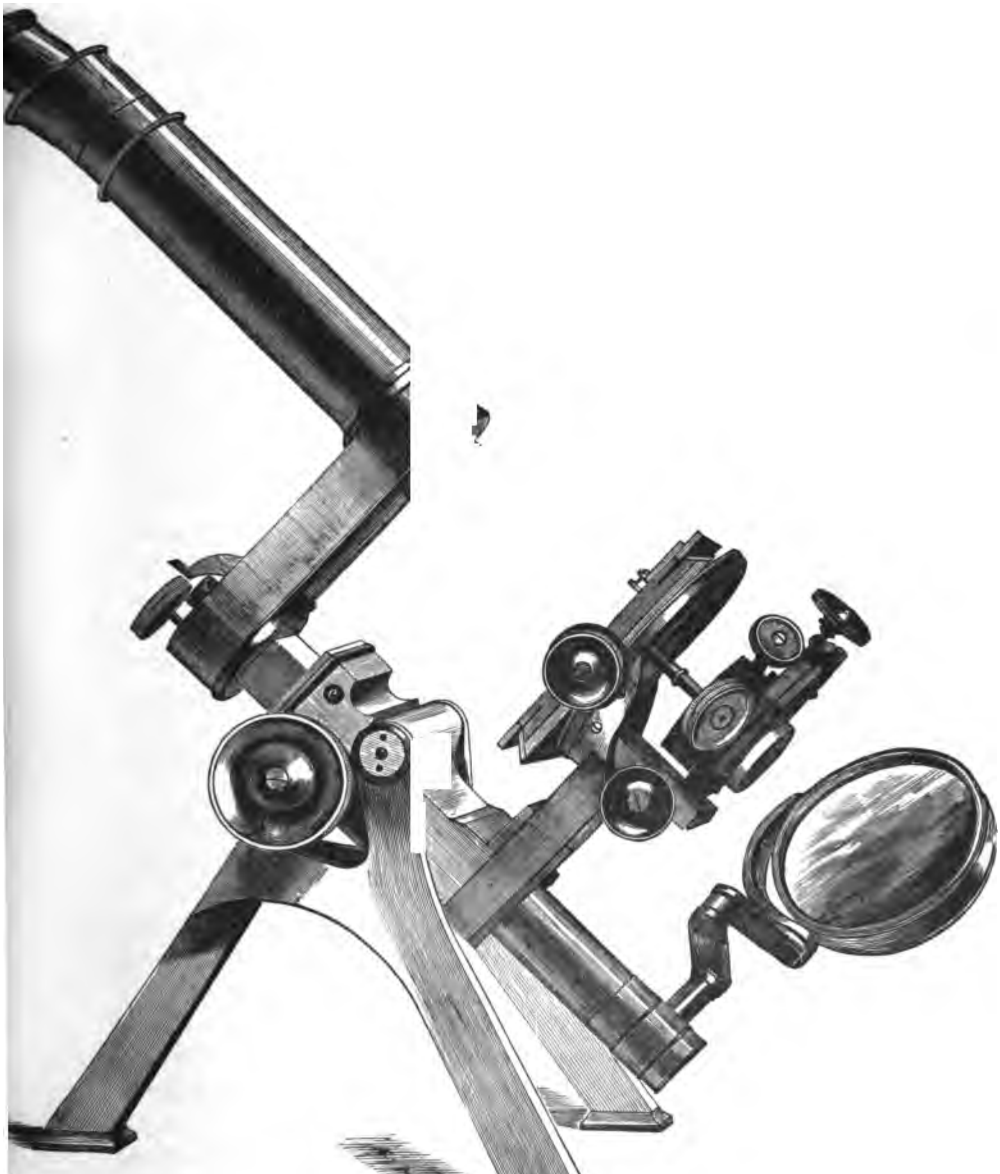


Fig. 1.

which pivot should be so arranged with the working part of the swing that the microscope shall be steady at whatever angle from vertical to horizontal it is placed. At true horizontality the tube should be stopped by a "stop" for the purpose. The body-tube of a stand for our work can hardly be too wide in diameter so long as we do not reach the point of inconvenience in adapting eye-pieces, etc., to the tube.

The finest stands made, so far as the writer knows, are those of Powell & Lealand, of London; they are perfect in rigidity, in mechanism, in workmanship and finish, and, though expensive, their owners say they are cheap in the long run.

A very good stand is the "Wales" pattern of Messrs. Swift and Son, London. (Fig. 2.) The advantage of this form of swing is that the centre of gravity is in the same position, and that a good one, to whatever angle the tube is swung. The writer used this stand for high power work with complete satisfaction, and that he gave it up was due not to the stand itself, but to certain exigencies which arose and could not be met with the then arrangement whereof this stand formed a part. Consequently this stand is highly recommended to those who desire a good stand for our purpose at a very moderate price considering the work, and the efficiency. For simple examination of objects, this stand fitted with a Differential Screw Fine Adjustment, is a most satisfactory instrument for any kind of work.

Beck's Stands, which are easily procurable in America, are probably in no way inferior to others, but we cannot speak from personal experience.

A most excellent stand is the one now exclusively used by the writer for photo-micrography. In general the stand is the so-called "Nelson" pattern, and the one in question was made by Mr. C. Baker, of London, specially for the writer. This stand was made extra heavy and strong in all parts, with a differential-screw fine adjustment most accurately fashioned, and there is a similar fine adjustment to the sub-stage. A very important feature not often attended to in stands of modest pretensions, is the rack work draw-tube for the correction of objectives not furnished with "correction collars,"

or with insufficient range of collar correction. In critical work with certain objectives this draw-tube is an absolute

FIG. 2.—SWIFT'S WALES STAND.

necessity, and the purchaser of a new outfit is recom mended to insist on a racking draw-tube, which will be found convenient in all cases, essential in some.

These are the stands of which we have some experience or knowledge, but there are doubtless other stands well adapted to our purpose. Many of the so-called Students' Stands are well and strongly made, their low price being due not so much to want of good material and work as to absence of all delicate and perhaps unnecessary mechanism. In particular, the pattern of Hartnack appears to us commendable among cheap but

FIG. 3.—BAKER'S "NELSON" STAND.

good microscope stands. One thing, however, in the cheaper class of stands ought always to be carefully tested before a purchase is made, the *fine adjustment* must work *true* and without jerk, deviation or "spring;" and it must be firm and not "give" in the slightest degree when the tube is at any angle. The long lever adjustment of Powell and Lealand's best stands is considered the acme of perfection, and the differential screw known as "Campbell's" is also very trustworthy when well made. Mr. Swift has lately devised an additional independent safety spring to be used in conjunction with the Campbell screw fine adjustment.

Doubtless, any well made stand may be used with complete success. Much very fine work has been produced with cheap microscopes not designed for photo-micrography; so that any one possessing any good microscope and a moderate amount of ingenuity and neatness of hand need not despair of success, should his pocket not admit of the purchase of a new and specially adapted stand. One of our diagrams will show how easily any stand may be used for photo-micrography at an odd time or in a casual way.

The *Objective*, or *Object Glass* is, on the whole, the most important part of the apparatus. The first essential is that it be "corrected for photography."* Objectives made for ordinary purposes of observation are usually "over-corrected," a term that requires explanation. The rays which give the best visual effect being less refrangible than those exercising the greatest influence on chemical compounds such as we employ in photography, the latter rays come to focus behind the focal point of the visual rays, and naturally lenses for ocular observation only are corrected for visual and not for actinic rays. Moreover, in order to overcome certain imperfections of image that would arise from the interposition between the object and the lens of the glass disc usually covering the object, and also to meet the fact that ordinary eye-pieces are not made achromatic, the objectives are still further corrected in such a way as still further to separate the visual from the actinic focus. The greater the principal focus (*i. e.* the lower the power) of the lens, the greater the distance between the foci, so that while with a high power objective the foci may practically correspond, with a low power they are so sensibly separated as to produce a blurred image in photography while visually the image was quite sharp. Of course, this would be fatal to photo-micrography. We must, therefore, either procure objectives corrected for photography, which is the best plan by far, or we must by the use of a supplementary lens so alter the whole combination that the visual and chemical rays shall

*The "correction," if not in the objective itself, may be obtained by use of an ocular made for the purpose, Corrections for chromatic and spherical aberrations are, of course, essential to all objectives.

focus exactly in one plane. This supplementary lens is usually a double convex fixed at the back of the objective-cell; it introduces extra reflecting surfaces which should be avoided, and it sensibly alters the focal length of the objective. By experiment the distance between the foci of any lens may be determined and allowance made before each exposure by withdrawing the sensitive plate from the objective to the amount determined by the experiments; but as the distance differs not only for each objective but also for each distance from object at which the objective is used, it is plain that such a necessity would be an intolerable infliction to most men. Many, if not all, opticians now produce objectives of all powers most accurately corrected for the actinic rays, and there is no extra cost involved. The new apochromatic object glasses used with projection oculars are perfect in this respect, and have so many other valuable qualities that we propose to devote a chapter, or at least a paragraph, to them solely.

A much vexed question is that of the angular apertures of objectives not only for photo-micrographic purposes but for general purposes of observation. "Resolution," or the power of separating visibly line from line, dot from dot, mark from mark, increases with angular aperture. Thus an objective having an angular aperture of 20 deg. will, with blue light, visibly separate lines about 18,000 to the inch, while a lens of 120 deg. will, under similar conditions, separate lines about 90,000 to the inch. (For further remarks on angular aperture, immersion, and numerical aperture, see Chapter XXIV, pages 162 et ssq.) But as aperture increases certain useful qualities fall off. A quality called "penetration" is known to fall off in proportion as aperture increases, and this matter requires investigation. "Penetration," as it is called in microscopy, "Depth of Focus," as it is called in photography, is a supposititious power of focusing, sufficiently sharply to prevent visible blur, simultaneously on several planes perpendicular to the optical axis of the system. Plainly the essence of the debate lies in the amount of blur visible or permissible. In a small photograph a very small area of confusion is permissible, while in a larger photograph a comparatively large area of confusion

is not only permissible, but preferable to over-sharpness *from an artistic point of view.* In photo-micrography as a science we have nothing to do with fine art, and scientifically speaking no blur or confusion-area is permissible at all. And further a lens cannot by any possibility focus equally sharply on any two planes perpendicular to its axis, and any *appearance* of equal sharpness can only be attained by a general sacrifice of sharpness, or by a compromise between absolute sharpness on one plane and absolute sharpness on another plane. When such a compromise is made the image may appear sharper generally, but that is simply because there being no absolute sharpness anywhere there is a lack of sharp to compare with unsharp, and so the eye is deceived into an imagination of sharpness. And yet again it is not the case that a compromising or "diffusing" lens gives the sharpest image as a whole, for a lens capable of giving the utmost definition on any one plane will certainly show adjacent planes proportionately sharper than the lens which is incapable of giving thorough definition on any plane. It is our belief that this misleading theory of penetration, promulgated and upheld by great authorities mistaken on this point, has done much mischief to microscopic optics, and led many an optician and many a worker astray. For purposes of rapid observation of moving objects, where general appearances are desired rather than critical examination, undoubtedly low angle "compromising" lenses are of the greatest service, but the writer ventures to assert, both as a theory and from careful and repeated experiment, that better photo-micrographs are produced, and presumably better images observed, by well-made, wide-angle lenses than by lenses made for "penetration," or stopped down so as to cut off available angle. Certainly many lenses are made so imperfectly that when they are used at their full available angle of aperture aberrations come in that spoil their performance altogether, but this is a mechanical not a theoretical fault. The writer regrets to say that all this is in flat contradiction to what he wrote with reprehensible precipitancy when he was but a beginner and a "smatterer" in this science. But granting the desirability of this quality of pene-

tration there is another matter to be considered. While it is true that penetration decreases in direct proportion as angular aperture increases, it is also true that penetration decreases much more rapidly as magnification increases. Penetration varies inversely as aperture but also inversely as the *square* of magnification. So that a low power with a wide angular aperture may be expected to yield a better result in the matter of penetration than a higher power with an equal aperture. As, therefore, aperture is the means whereby we gain resolution and definition, and as magnification can be obtained in other ways than by the use of a high power objective, the advantage clearly lies with the use of a low power of wide angle, magnification being obtained by stretch of camera, eyepiecing, or "camera enlargement" of the original negative. The limit to the angular aperture of a glass in proportion to its focal length is a difficulty of optical mechanism. Beyond a certain point angular aperture in high proportion to focal length cannot be achieved by practical opticians.

There is, however, one defect inseparable from the use of very wide angled objectives, and as it was noticed by Dr. Carpenter in his great book, "The Microscope and its Revelations" (London: Churchill. Sixth edition, 1881), it may well be put in his own words. After dwelling upon the difficulty of perfectly correcting a wide-angled lens for spherical and chromatic aberrations, and after pointing out the advantages in this respect gained by the system of homogeneous immersion, he proceeds thus: "But here comes in another source of impairment—*the difference in the perspective views of every object not a mere mathematical point or line which are received through the different parts of the area of the objective.*" Dr. Carpenter then quotes in support of his position such high authorities as Dr. Royston Piggott, and Messrs. Dallinger and Drysdale. We might admit this defect more readily if we were certain that "perspective" can exist in a diffraction image, but we still believe that even if Dr. Carpenter's view be correct, better results on the whole will be obtained by the use of as wide angles as can be used without serious amounts of aberration.

"Working distance" is also apt to be curtailed by largeness of angle. "Working distance" is simply the distance between the object and the front combination of the objective. With low powers this is of little moment, but where we come to use high power objectives their performance is not only apt to be impaired by very close working, but there is a danger of damage to object or objective itself. Homogeneous immersion helps us out of the trouble to some extent, but with cheap immersion lenses of numerical aperture 1.25 and over, we have repeatedly failed to observe objects that happened to have cover glasses thicker than usual.

The "power" of an objective is frequently very loosely quoted. "Power" depends on focal length, and the focal length of a compound lens is usually quoted by a supposititious comparison with a single lens of given construction. The real focal length of an objective, and consequently its amplifying power, are very seldom accurately stated, even by the best makers. If it is necessary to know the exact magnification of any object with any objective at any distance, recourse must be had to measurement by a stage or other micrometer. The lower the power of an objective the more difficult it is to give it wide angular aperture, consequently objectives which pretend to wide angles are usually quoted under their real power, *i. e.*, over their real focal length. And tolerance of eye-piecing is a very important factor in calculations as to power, for a quarter-inch *o. g.* may stand an ocular of twice the power that a one-sixth can bear, and so after all the one-fourth may come to be the higher power. Well-made objectives will give good images with oculars that will break down inferior lenses, and a lens before purchase should always be tested with a high ocular; there is no better trial that can be rapidly made.

There are certain proverbial tests for microscopic objectives, and a glass is quoted as resolving this, that or the other test structure. This is all very well if the tester be the owner of the test object, and know it well. But opticians always have test objects of their own, which, we need not say, are intended for testing lenses to the satisfaction of would-be purchasers. An optician's podura scale, or "blowfly's tongue," is generally

easier of resolution than any to be found in the cabinet at home, and an optician is likely to choose a pretty even section of an echinus spine as a test for flatness of field. Flatness of field is a highly important quality in an objective for general photo-micrography, and depends chiefly on skilful work on the optician's part. Want of this quality may be hidden by diaphragms in the ocular, and often is so in badly made apparatus.

Finally, it may be said that the tyro microscopist is not capable of making a wise selection of objectives for photo-micrography or any purpose, but an experienced worker will be able to select the good lenses at once in all points except actinic correction, and on that point the optician's word must be taken if trial of the lens is not permitted. The beginner ought therefore to get a skilled friend to choose the lenses for him. We should consider the following to be a complete battery of objectives, provided they were of first-class construction: 3 inch; $1\frac{1}{2}$ inch or 2 inch; 1 inch; $\frac{1}{2}$; $\frac{1}{4}$; $\frac{1}{8}$; $\frac{1}{12}$.

CHAPTER IV.

OPTICAL APPARATUS CONTINUED.

The Condenser is almost of equal importance with the objective, and certainly the best object glass cannot be expected to work at its best without a good condenser properly used. A non-achromatized object glass is so evidently useless that no one is likely to be taken in by one, but—perhaps unfortunately—a non-achromatic condenser is often found a very tolerable makeshift for an achromatic one. At all events, those who cannot afford to buy an achromatic condenser need not despair of producing very fine work, though [perhaps the very finest is beyond their reach.

For the lowest powers usually employed in our work, however desirable a substage condenser may be, certain difficulties of illumination preclude the use of a condenser, and a bull's-eye must suffice. But for all objectives of one inch and higher power we strongly recommend the use of a substage condenser; the bull's-eye also may be used if necessary. The cheaper and commoner kinds of condenser are non-achromatic, consisting usually of three elements and varying in angular aperture from low figures up to the numerical aperture 1.4 as made by Zeiss and others, the latter being of course oil immersion condensers. For lower power work—up to (say) the ordinary four-tenths o. g. of about 90 deg.—the front element should be removed from the condenser; this front is usually fitted with a metal cap pierced with a very small hole for centering purposes. Even the third or lowest element may be used alone as a condenser, but as a rule it is better either to use the two lower elements or to omit the condenser entirely.

Achromatic Substage Condensers are now made by all opticians and used, so far as we know, by all good microscopists aiming at the best results of either observation or

delineation. These condensers are usually of three combinations, and range to the highest attainable immersion apertures. The best that has ever come under the notice of the writer is the Apochromatic Immersion Condenser of Powell and Lealand, giving an immersion angle of *N. A.* 1.4 or even higher. The focal length of this condenser is about one-fifth of an inch, so that in the absence of a bull's-eye—which the writer never uses with this condenser—the illuminated field is but small unless the power of objective used be high ; for critical work this shortness of focus is an advantage. The price of achromatic condensers of high angle is considerable, but their superiority over non-achromatic condensers is great. Messrs. Beck, Swift, and probably all opticians make achromatic condensers to nearly the full extent of the air angle, but one of 140 deg. will be found a very useful condenser where the pocket does not permit of more than a few pounds of expense.

FIG. 4.—IRIS DIAPHRAGM.

The condenser, as will be more fully shown hereafter, is not so much a device for throwing a blaze of light upon the object, as for (1st) focusing the light at a certain point, and (2nd) modifying the angle and the direction of the light. Accordingly the condenser is furnished with various accessories which must be named here, though their precise use must wait till a later time. A set of diaphragms usually accompanies the condenser, and these have apertures graduated in size from the full aperture of the optical part of the condenser down to very small holes, the smallest of all usually serves for centering. An exceeding great convenience is the Iris Diaphragm, Fig. 4,

the nature of which explains itself to anyone looking at our cut. The manufacture, however, is by no means so simple, and the purchaser ought to see that the interior of the aperture is as nearly circular as possible, and that, in closing, the segments do not "jam," or work very tightly, a very common fault. The segments should not "lock," that is should not interlace with each other, for that construction generally means a "jam."

Another accessory usually accompanying a condenser is a set of "black-ground discs," the nature of which will be understood from figure 6 and the use of which will be treated later.

FIG. 5.—POWELL AND LEALAND'S APOCHROMATIC CONDENSER *N. A.* 1.4

Frequently also other "stops" accompanying the condenser, we figure three of them here, so that their description may be recognised when we come to mention their uses.

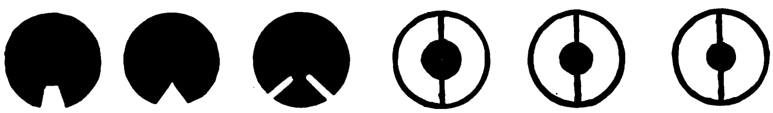


FIG. 6.—STOPS.

There are various other accessories frequently fitted to the substage of a microscope, sometimes to be used along with the condenser, sometimes independent of the condenser. Thus a polariser, with or without selenite discs, is often made to fit the substage; colored glasses, technically called "light modifiers" are also common accompaniments of an achro-

matic substage condenser. Indeed, condensers are frequently mounted so as to carry all or several of the accessories described, and to carry them all at once; while the writer admits the ingenuity, and even the occasional convenience of such arrangements, he hardly ventures to recommend their use. Arrangements of this kind are apt to be heavy, clumsy, bulky and puzzling, and it is on the whole better to have on the substage at the time of work only as many of these accessories as are actually in use. Still it may suit some tastes and some purses to adopt one of these multiplex arrangements, and one is figured here as a sample of the usual article.

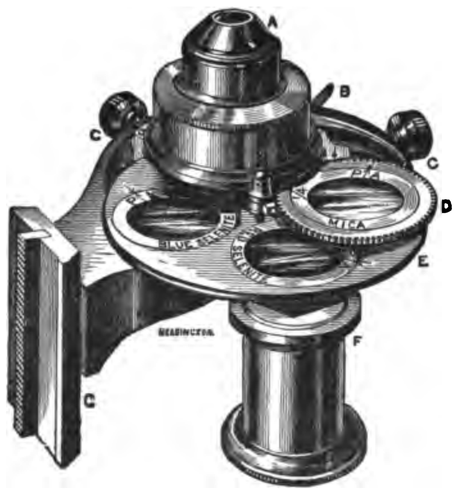


FIG. 7.—A FITTED SUBSTAGE CONDENSER—ACHROMATIC.—*Swift.*

Another common contrivance for facilitation of work and for convenience of manipulation is a nose-piece, double, triple, or even quadruple (Fig. 8). While admitting the convenience of this contrivance the writer does not recommend its use, for delicate work at all events. The less load we have on the microscope tube, especially near the objective, the better; cases have occurred of injury to the working of a delicate fine adjustment screw by a heavy nose-piece. Greatly to be preferred for efficiency and for economy, and not a whit behind

in facility and elegance, is a simple adapter with a bayonet joint made by filing away part of the thread of the adapter, and part of that of the microscope tube. A lens can be screwed into the latter in the usual way just as if the tube-thread were complete.

FIG. 8.—TRIPLE NOSE-PIECE.

The objective screws into one end of the adapter in the usual way, then the other end of the adapter is pushed straight into the threaded end of the microscope tube and gets a short turn in one direction, when it is at once clamped. These adapters are easily made, small, cheap, and several can be had for a few shillings.

No mention has been yet made of oculars, because the writer has no confidence in any ocular except those made specially for projection, and projection oculars shall be treated in a separate chapter along with apochromatic objectives. It is not by any means asserted that no ocular of the ordinary type may be successfully used in photo-micrography, but the writer has never yet been satisfied with the performance in this work of any ocular, achromatic or otherwise, except the projection oculars. It is not denied that in some cases good results have been obtained with ordinary eye-pieces, but the writer has never yet ascertained on what fortuitous circumstances the success has depended. "Fortuitous" is written advisedly, for by its construction an ordinary ocular is evidently not intended to project an image, except on the human retina. It is to be noted that an ordinary objective is "over-corrected," a Huyghenian ocular under-corrected, so the two often balance each other.

Nor does the writer commit himself to any opinion as to the merits of a contrivance known as an "Amplifier," and consisting of an achromatic concavo-convex or double-concave lens inserted behind the object glass; he has not himself tried such an arrangement, but has seen specimens of work produced with its aid which do not seem to speak highly in its favor, though *per contra* he has seen very creditable work produced in its presence.

FIG. 9.—BULLS'S-EYE ON STAND.

The bull's-eye does not require special mention in this chapter; it is usually a plano-convex glass used with its plane surface next to the radiant, and the larger it is, without being clumsy, the better, though by some a small bull's-eye is preferred. A small bull's-eye, having a shorter focus, gives more brilliant illumination than a large one.

CHAPTER V.

ILLUMINATION.

PRACTICALLY we have to consider only five radiants: Sunlight direct, daylight diffused, electric light, oxy-hydrogen limelight, and lamplight from some form of oil lamp. Magnesium light we must at once put aside, because, while it has been successfully used for exposures of very brief duration, it is out of the question for prolonged exposures on the scores of inconvenience and expense, and some of our objects will require prolonged exposures to any light however powerful. The light produced by carburetted hydrogen burned at the orifice of an ordinary "gas-burner" has several qualities which render it useless for our purpose, and no system known to us of burning this gas alone is at all suited to our purpose. Admittedly, however, the incandescence of certain materials impregnated with such refractory substances as zirconium salts, the incandescence being produced by ordinary "gas" suitably used, gives some promise of future utility, though as yet we have not been able to utilize any contrivances such as the "Welsbach" burner, and efforts on our part have not been wanting.

In past years, before our photographic preparations had attained the degree of sensitiveness to light that they have now, duration of exposure was often a very important consideration, and it was little wonder that direct sunlight was invariably used for certain work, where with even the most powerful of artificial lights the exposure must have extended to many hours. The duration of exposure is *per se* of little consequence, but the danger of tremor and change of temperature are much more serious matters.

The use of direct sunlight involves, in most cases, the use of a heliostat, and in all cases a vast amount of uncertainty.

In Great Britain, at all events, the use of direct sunlight may be set aside as not available, certainly as not presenting sufficient advantages to counteract its enormous disadvantages, and in America there is no longer the necessity for it that there was in the days of Woodward's achievements. No work on photo-micrography, however, could pretend to be complete without something more than an allusion to sunlight illumination, so we shall present a diagram of the arrangement used by Woodward, an arrangement which in many respects formed the basis of future developments.

Messrs. Truan and Witt, in the production by wet collodion of a fine series of photo-micrographs representing certain Diatomaecæ of Hayti, used an apparatus wherein direct sunlight was projected by means of the mirror of a Chevalier megascope.

Dr. Woodward, after using the arrangement figured No. 10, made alterations which he considered improvements and which in some respects undoubtedly were steps in the right direction. He used a room as his camera, supporting his sensitive plate on an easel which was made to run on rails to and from the microscope which, with objectives, was fixed to the window shutter, the light, as before, being reflected through the optical system by a heliostat. The obvious disadvantage of this arrangement was the fact that in case of any tremor the sensitive plate and the optical system might not move together. Dr. Maddox used also a darkened room, but he had in the room a camera, reflecting the sunlight by means of a mirror and prism through the optical system which was fitted to a hole made in the shutter. Non-actinic light was admitted into the room by means of suitable "light-filtering" media. Many other arrangements might be mentioned without any notable difference from or superiority over these already touched.

An important feature in sunlight illumination is the use of "monochromatic" light. The reader is probably aware that the rays composing a beam of white light are not all equally energetic in producing the chemical action necessary to the production of a photographic image. The waves of light producing the sensation of sight vary in length from

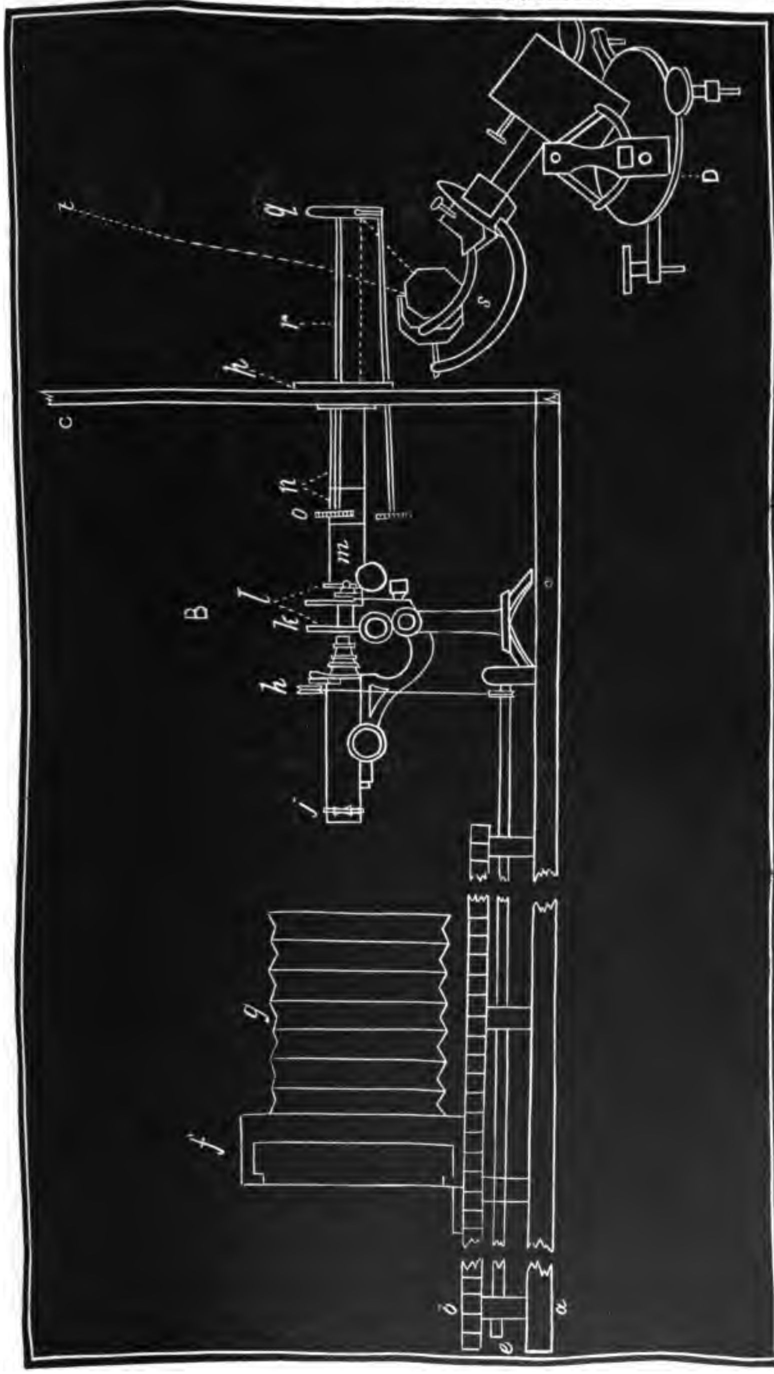


FIG. 10. (From Dr. Beale's "How to Work with the Microscope.")

crest to crest, from—roughly—$\frac{1}{36000}$th to $\frac{1}{65000}$th of an inch; and of these varying wave-lengths those which exercise the greatest chemical action measure about $\frac{1}{64000}$th of an inch, and are what we call "violet" in color. If, then, we can cut off all rays except those which exercise strong chemical action, we shall reduce the general actinic force of the white ray,—for all visible rays have *some* actinism,—but we shall have less confusion among the rays producing the photographic image, and so our optical apparatus will probably be used at its best, especially if our lenses are corrected for the rays which produce the best *visual* effect, as lenses naturally are when intended for ocular observation only. Two methods were in vogue for this passing of actinic rays alone: one was the use of a cell containing cupric ammonio-sulphate dissolved in water, which makes a blue solution, and one spectroscopically suitable for the purpose aimed at;* the other plan consisted in the use of a prism which broke up the white ray into its component parts, the blue part alone being allowed to pass through the microscope. A "diffraction grating" would yield a still purer spectrum, but so far as we know has not been used for this purpose. In each case the solar ray was passed through the monochromatising medium before it reached the object.

Diffused daylight may be utilized by reflection from white cloud or uniform blue sky; but after repeated and careful experiments the writer can not recommend this system of illumination as likely to prove satisfactory to the serious photo-micrographer. If white cloud or homogeneous sky can be depended on, the ordinary plane mirror of the microscope, if of ample size, will answer; all rays in this case being practically parallel at their impact on the mirror. Another plan, tested by the writer with greater success, is to omit the mirror and to replace it by a white surface, as very fine filter or blotting paper, but not a shiny surface as sized paper or opal glass. The white surface is to be inclined in a suitable direction at an angle of about 45 deg. to the axis of the optical system.

*This solution is, in the writer's experience, usually far from monochromatic and decidedly inferior to certain qualities of cobalt blue glass for this purpose.

The electric light has been used with great success in this connection, an arc lamp having been the usual form. There is no doubt that an arc light, provided it is steady, may be expected to work grandly for our purpose. It is in most cases, however, expensive, difficult to work to perfection, and when imperfectly worked, a very serious botheration. As the writer has no experience of the arc light he refrains from making any statements as to its suitability or unsuitability for our purpose. Incandescent filaments in electric lamps might be made answerable to our purpose, but so far as we know no incandescent electric lamp has yet been found equal even to a good oil lamp, the area of incandescence being too slender in the former.

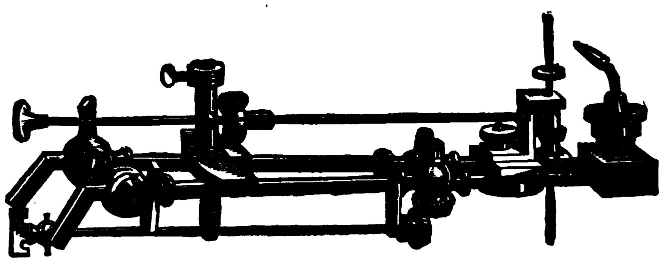


FIG. 11.—OXY-HYDROGEN JET BY NEWTON. AUTHOR'S "CUT-OFF."

The writer uses the lime light as his radiant in nearly all his work, and, taken as a whole, this light is as nearly perfect for the purpose as any illuminant at present known. The general form of a lime-jet is well known, and the ordinary form of "blow-through" or "mixing" jet will doubtless suffice for all purposes. The blow-through jet gives a larger area of incandescent lime, but the incandescence is not so perfect, nor the color nearly so good as that produced by the mixed gases. There is no necessity for any great pressure of the gases, provided the proportion of one gas to the other is suitable, and the nipple of the jet has a bore suitable to the other circumstances. All these matters may be settled by experiment, and, in fact, *must* be so settled. The writer uses a mixing jet, but takes the hydrogen direct from the house main, while he puts the oxygen in a bag and puts thereon only a moderate pressure;

in fact, on a pressure board four feet by three feet, he places a weight of forty pounds.* Figure 11, representing a jet arrangement designed by the writer, requires some explanation.

The jet is an ordinary mixing jet, but has an extra attachment consisting of three cogged wheels worked from the back of the jet by the cross piece and operating two taps, one on the O and the other on the H tube. These tubes are operated proportionally by the equal cogged wheels, so that the light being once arranged at its best, both of these extra taps being full open, the brilliance of the light can be lessened without injury to the quality by simply turning the cross-piece. But the H tap has a "bye pass," so that the hydrogen can not be entirely cut off by this tap, while the oxygen is a complete cut off. The result is that the lime never gets quite cold when the gases are not turned up, and there is no need to light the jet each time after it has been temporarily out of use. Moreover, by lowering the gases together the worker saves his eyes; and by turning the extra arrangement entirely down leaving only a glimmer of hydrogen burning, the worker saves his time, his lime and his money. The harder the lime the better for our purpose, for a large area of incandescence, unequal in brilliance and color, is most puzzling and pernicious. The jet figured is made by Messrs. Newton & Co., of London, but is open to the public, being in no way "protected." For a very brilliant light with a small incandescent area—as for work of the greatest delicacy—both gases should be put under heavy pressure in bags, or preferably, cylinders. Mr. E. M. Nelson has his gases in iron tanks, and gets a very fine light indeed.

The writer has on several occasions attempted to work out some medium to replace "limes" which crack at awkward times, and are at all times liable to disintegration through access of damp. Magnesia pounded very thoroughly for two hours in a mortar with sufficient water to form a paste promised well. "Buttons" were made with the paste, each button

*Since the introduction of Beard's excellent "Regulator," the writer has given up bags, and uses oxygen from the cylinder, pressure being controlled by the regulator.

impaled with a short length of platinum wire, and then gradually dried, first in a heated iron oven, then in coal gas flame, lastly in the oxy-hydrogen flame, as suggested by Dr. Roux of Paris; but the result seemed decidedly inferior to the ordinary lime. Zirconium oxide was also tried with no better success.

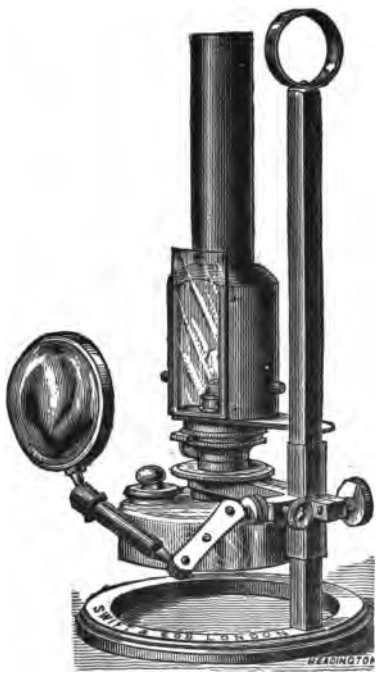
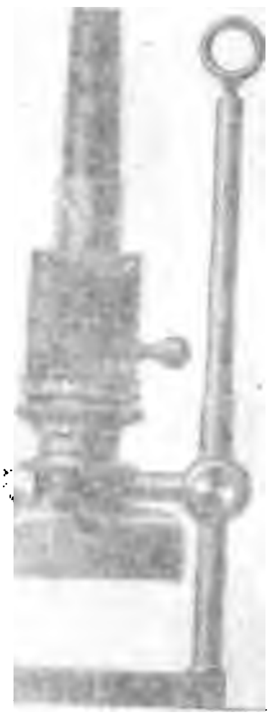


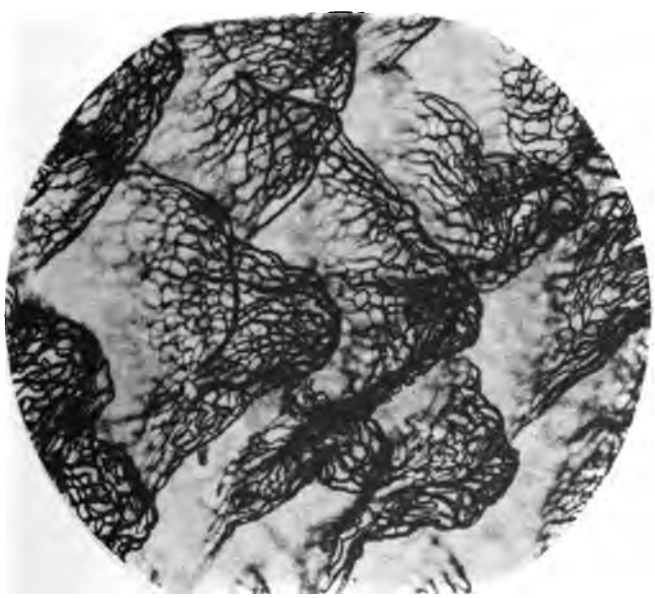
FIG. 12.—SWIFT' MICROSCOPE LAMP.

Probably most of our readers will find an oil lamp answer all desired purposes, and if time be no object, a good oil lamp will probably prove entirely satisfactory. If the wick be single and flat, and if it can be turned either broadside or edge to the microscope, the kind of lamp is practically immaterial. But lamps are made specially for this work and several of them may safely be recommended. Mr. Swift's lamp (fig.12), for instance, has served the writer thoroughly well, and the lamp figured No. 13 is also well adapted for this work.



... the lamp ... front of the flame ... when the flame is ... this the slips ... cloth ... for two hours in ...

No. 1.—Hairs on Proboscis of Blowfly, × 875.



No. 2.—Injected Villi, Intestine of Rabbit, × 30.

PLATE I.

CHAPTER VI.

PHOTO-MICROGRAPHIC APPARATUS.

After what has been written about the component parts, the entire system of apparatus ought to be easily understood. No matter what microscope-stand or what light is to be used, some ingenuity and care will be required to fit the several parts together so that the action of the whole may be efficient and sure. If a complete photo-micrographic apparatus be bought ready for use, of course the purchaser, having once satisfied himself of the accuracy and convenience of the apparatus, need no further trouble himself on this score.

Exceedingly good work has been done and may be done again without any special apparatus beyond a microscope and a camera. The microscope has only to be turned to the horizontal, a camera run up to the eye piece end of the microscope, all light not passing through the optical system excluded by means of a velvet tube or cone passed from a photographic lens tube, (the glasses being removed) to and over the end of the microscope tube, the whole presenting an appearance somewhat as shown in fig. 14.

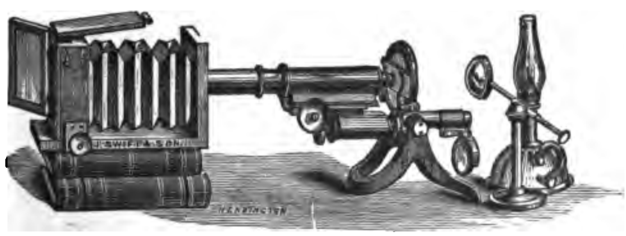


Fig. 14.—Simple Arrangement of Microscope and Camera.

It need hardly be said that with such an arrangement great care is necessary to prevent shaking, and to preserve the due relation of parts. In all apparatus for this purpose two salient

necessities must be attended to; 1st. The light, the condensing system, the object glass and the centre of the sensitive plate must all be axially centred to each other; and 2nd. The object and the sensitive plate must be parallel to each other and perfectly perpendicular to the optical axis of the system. The slightest divergence from either of these relations will entail failure.

Where the intending photo-micrographer possesses the component parts of the system, as microscope, lamp, and camera, and requires only to fix these in suitable position on some base to be used permanently, the matter lies chiefly with himself, and the ease of his operations will depend chiefly on the instruments he happens to have. We shall figure and describe two arrangements at least; one a sample of an apparatus sold ready made, the other an apparatus built up of miscellaneous materials by the writer, and these are given merely as suggestions and as examples of what has been found to work well in the writer's hands.

In Britain of late years, several opticians have stocked apparatus of which figure 15 is a type. It presents all the useful features of its class, though other instruments are to be found differing in detail, some details being superior, others inferior, to those seen in the cut.

This apparatus was, the writer believes, designed in the form shown by Professor E. M. Crookshank, and used by him in his photo-micrography of Bacteria. The writer has used an apparatus in all essential points similar to that figured, and had great satisfaction in its use. The stand is so made that when it is necessary to have the stage of the microscope horizontal, as shown in Fig. 15, as when for photography of liquid matter, the base board can be let down to the vertical position; as every part of the optical and photographic and illuminating systems is clamped to the base board, this position is easily attained; and, except where a lamp burning same liquid is used, one position is as manageable as the other. If an oil lamp furnishes the light a mirror must come into requisition. A point on which the writer lays great stress is: the microscope, condensing system and radiant are all fixed to one

platform which turns or a central pivot, so that the optical system can be turned out from the axial line of the entire sys-

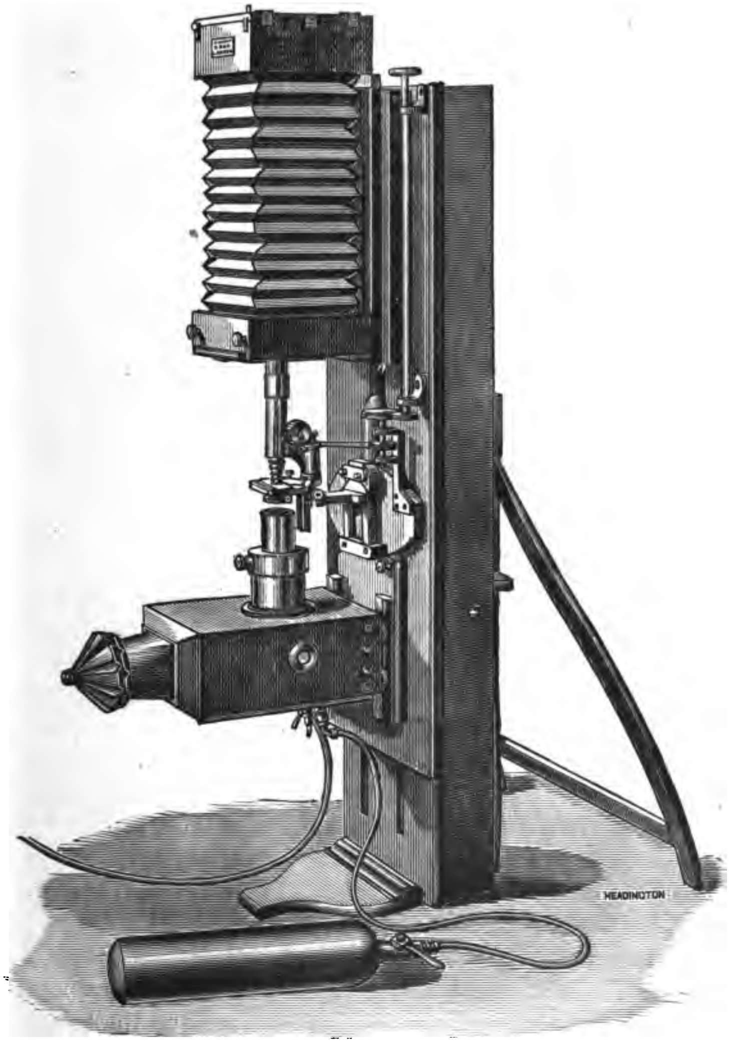


FIG. 15.—PHOTO-MICROGRAPHIC APPARATUS BY SWIFT, SHOWN AT THE VERTICAL POSITION.

tem, the object can be examined, corrections of the objectives studied, and everything focused and centered with the eye-

piece, the operator being in a comfortable and convenient position, sitting or standing, as desired. These things being done, the platform is turned back to a "stop" which is so arranged by the maker of the apparatus that the optical system is then axially centered with the photographic system. The focusing on the plane of the sensitive plate alone remains to be performed, and this is done by means of the rod seen in the cut. The rod has a pulley, the fine adjustment has a screw with a grooved milled head, and a pulley passing over the rod-pulley and round the grooved milled head operates the fine adjustment at the will of the operator examining the image on the focusing screen of the camera. A "Hooke's Joint" may be used in place of this focusing arrangement, the writer used that contrivance for some time, but on the whole an arrangement with rigid rod and pulleys is to be preferred.

Figure 16 shows the writer's latest arrangement, which combines some ideas gathered from Mr. Nelson's apparatus with others of the apparatus last figured, and still others which occurred one by one to the writer as he advanced in experience. The platform carrying light and optical system and turning on its pivot is retained, so also is the rigid rod and pulley contrivance. The platform is still "stopped" at a certain point, but this time the camera is entirely free on a very heavy teak base to which also the swinging platform is attached. In Fig. 15, after the optical part is stopped at the axis, the front only of the camera is run forward to meet the ocular end of the microscope tube; but in Fig. 16 the whole camera is pushed forward to the cap on the tube, and in both cases a smaller cap fixed to the camera fits very loosely inside a larger cap on the microscope tube. There is no difficulty in centering the latter arrangement, Fig. 16, for the centre of the camera focusing-screen is marked, and if the centre of the object coincides with the centre of the ground glass everything must be centered and perpendicular to the general axis.

Any photographic camera will answer for this work provided it be light-tight, and reasonably well made. No "motions," such as "swing-backs," are required. The camera

shown in Fig. 16 is one for a plate $7\frac{1}{4}$x$5\frac{1}{4}$ inches that happened to be in the writer's possession. The bellows arrange-

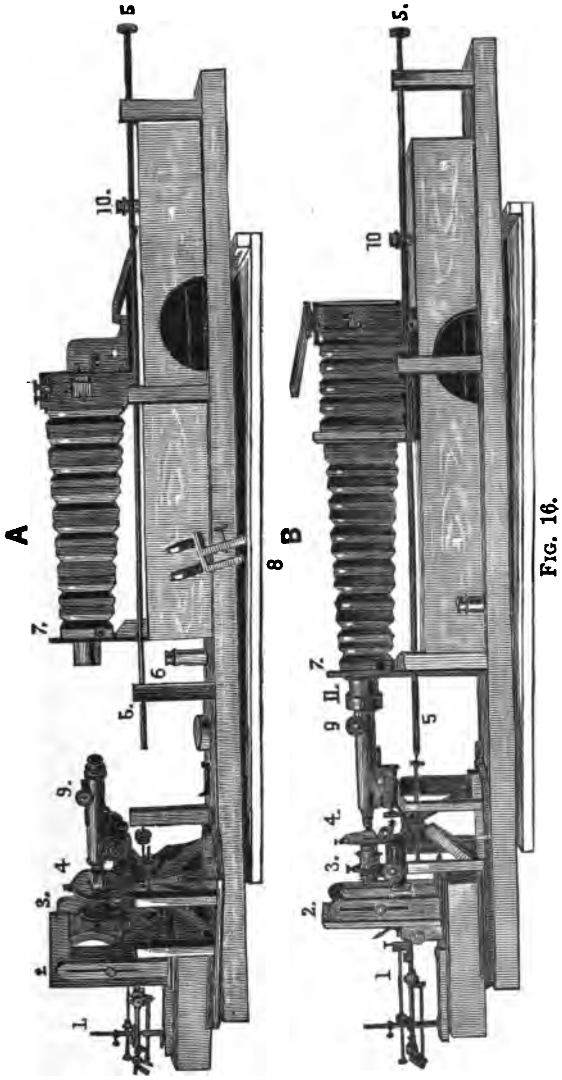


FIG. 16.

A. Apparatus during examination of object.
B. Apparatus ready for focusing.
1. Lantern, with body removed, showing o. h. jet (see Fig. 11).
2. Placed over alum trough.
3. Placed over substage condenser, centering screw seen.
4. Placed over fine adjustment screw, operated by cord passing round milled head and round pulleys on.
5. Focusing rod, with square fitting at end next light.
6. (in *A*) Projection Ocular.
7. Placed over screw-head operating flap-shutter inside camera.
8. (in *A*) placed under author's *bull's eye and ground-glass* arrangement (see Fig. 26).
9. Placed over rack for tube-length adjustment.
10. (in *B*) over Zeiss "aplanat" focusing eye-piece.
11. Leather cap to exclude stray light.

ment is very useful though not essential, and the same applies to the rack and pinion. The available stretch of the camera,

including the supplementary tapered bellows seen in front, is 30 inches without using the rack and pinion; an extra length of 10 inches can be added at will. The writer has an attachment to the apparatus, Fig. 16, by which he can increase his stretch of camera to 7 feet 6 inches, and his plate to 10x8 inches, but this is hardly ever used and never has been used with real success. A stretch of 40 inches from micro-tube to plate is perhaps the limit of utility, for very few object glasses will stand more than that stretch in the writer's experience, especially with oculars.

The largest useful size of plate is about 7x5 inches, or what is called in England "half-plate," 6½x4¾ inches. The camera should take a plate of one of these sizes, but should have "carriers" or "kits" fitting the "dark slide" to take 5x4 or 4¼x3¼ plates, the latter being technically called "quarter-plates." Square plates are probably better than oblong ones as a rule, so that the carriers may be made for 4¼ inch square plates, but plates of unusual sizes are not so readily obtained as common sizes.

One point regarding the dark slide is very important; it should on no account slide into its position in the camera by a long groove, but should be so made as to slide only about an inch, or better still it should fall into a groove at the lower side and be held into position by a catch at the top. There is very little danger of light fog in this region of our apparatus, especially as the room should be darkened (see later); and there *is* very great danger of moving some part of the apparatus after all is focused if the operator has to exert any force to shove the slide into position. The shutter of the dark slide must also work very easily and sweetly for the same reason.

The camera has of course a "ground glass," which is used for preliminary examination of the image upon the screen, and in certain cases the ground glass if *finely* ground is all-sufficient. In any case the ground surface may with advantage be oiled; but even then the surface is too coarse for focusing images with very fine details. Many devices have been used and recommended for producing a surface sufficiently fine yet with

sufficient grain to show an image. A sensitive gelatine plate exposed for a second to light, developed, fixed, washed and slightly treated with mercuric bichloride gives a good surface; this, we believe, orginated with Mr. Walmsley. No better focusing surface will be found than a piece of glass with some diamond marks on the front—that is on the side next the light. In the writer's case these marks consist of a cross, the arms of which are inches divided into tenths with a diamond; when viewing the image with the focusing eye-piece, if the magnification be known, it is easy to measure objects and distances at a glance. No image can be seen on the plain glass unless an eye-piece be used to focus the aerial image; the glass in fact is used only as a rest for the focusing eye-piece. The eye-piece used is known as a Ramsden, or perhaps better a Zeiss "aplanatic magnifier" may be used. In either case the scratches on the front of the focusing glass must be most carefully focused with the eye-piece; if is found difficult to focus the scratches, a fly's wing or some such object may be fixed to the front of the glass plate and the magnifier set to focus on that. It goes without saying that the focusing screen—or ruled glass or whatever it is—should be in the same plane as that occupied later by the sensitive plate. The rays, however, in ordinary work are at the sensitive plate so nearly parallel that slight "want of register" between plate and focus-screen is not so very fatal as many think. Dr. Bousfield, whom no one need fear to follow, uses no glass plate at all, nor fixes his focusing eye-piece at any point as many do, but focuses the aerial image in air alone; none the less the glass plate affords a convenient rest for the Ramsden or Aplanatic, but there must be no heavy pressure of focuser on screen.

There are many other ways of producing a focusing screen but probably the best have been here noticed.

It is important to have an arrangement inside the camera for starting and stopping the exposure. At "7" on Fig. 16 is seen the exterior of a simple flap shutter, the flap inside being operated by the button outside. Sometimes when a very rapid exposure is required and when consequently there is fear of moving the whole apparatus, we close this flap, open the dark

slide shutter in the usual way, then taking a square of blackened cardboard in (say) the right hand and holding it close behind, but not touching the substage condenser so as to shut all light from the object, we open the flap with the left hand and swiftly raise and lower the card in the right hand, thereafter immediately closing the flap. Where the hand is unable to make a sufficiently quick exposure, we rig up a photographic instantaneous shutter between light and condenser, and proceed with this shutter on the same principles as we did with the cardboard.

There is a fine field open to the mechanic in the designing of apparatus for photo-micrography; but the writer can only say that after long and varied work with the apparatus, figured No. 16, which was put together chiefly by Mr. Baker of London, he is at a loss to suggest any improvement on it.

A cell or trough of wood with plate-glass sides contains a saturated solution of common alum or in certain cases a solution of cupric ammonio-sulphate. These solutions, or the water of them, should be well boiled to drive off air, which, if the boiling is omitted, rises in bubbles from the bottom when the solution begins to get heated as it does with the oxyhydrogen limelight. This alum cell is necessary when the limelight or any other illuminating arrangement generating considerable heat is used. In high-power work changes of temperature have a very marked effect on the sharpness of image in the negative. (See Fig. 16, 2.)

CHAPTER VII.

REQUISITES FOR PHOTOGRAPHY.

HAVING already remarked upon the advantages of ample dark-room accommodation, running water and a waste-sink, we may now enter somewhat into detail regarding dark-room arrangements and articles used in operations purely photographic.

In arranging for non-actinic illumination the reader is advised to prepare himself at the outset for "color correct" or "orthochromatic" photography, for the worker at general photo-micrography, if he pay any attention whatever to the words of the author of this book, will very early find himself using color-sensitive plates. This means that whether the the reader proposes to use as a general rule yellow diffused, or clear ruby light, he must provide himself at all events with ruby illumination. If development is to be conducted by daylight we recommend that the outer sash of the window be glazed with yellow glass, or at least three thicknesses of "canary medium" known to all photographic dealers. For ordinary plates a sash of ruby glass should be added to the yellow glass, and the best—in fact practically the only good ruby glass—is "flashed ruby" on one side and "stained yellow" on the other. A splendid glass, if it can be got, is flashed deep ruby on one side and *ground* on the other side. The three thicknesses of canary medium may suffice if the light shining on it be not very strong, and if a thickness of good ruby glass be added, or two layers of good "ruby fabric," the window is probably trustworthy for even ortho-chromatic plates. If artificial light be used the flashed and stained ruby glass may suffice in a single thickness for even color-correct plates, though this must be tested; it will almost certainly suffice for any ordinary plates; two thicknesses of the canary medium for ordinary plates, with the addition of ruby glass as before for

"ortho" plates, may be taken as "safe." To test a light for safety, place a plate of the kind to be used half in the leaves of a book, expose for (say) four minutes at the spot where the operation of development is to be conducted, thereafter develop the plate as much as possible in total darkness, and it will be easy to discover if the light is unsafe, for, if it is unsafe, the half that projected from the book will "take a tint," in other words, will develop darker than the part which the book protected. It is vastly important in photo-micrography to see exactly what the plate does under development, but in order to examine the plate critically, no great space of time is necessary; the *rationale* of the light question may therefore be summed up: Use the greatest possible amount of *safe* light, but do not waste any light; that is, do not expose the plate to light, however safe, when no object is gained by such exposure.

Non-actinic lamps are held in stock by all photo dealers; we figure one:

FIG. 17.—DARK ROOM LAMP.—Carbutt.

A wooden sink lined with sheet lead seems preferable to iron or earthenware, and in the sink should be a wooden "hatch" or grating on which measures, bottles, etc., may stand and drip. On one side at least of the sink should be a ledge or table sloping down to the sink and lined with lead or covered with rubber or American cloth, so that dripping dishes, etc., may be laid on the slope and their drippings run into the sink.

The end of the water-tap should have a thread by which may be coupled on to it such conveniences as a rose, a rubber tube, etc. If none of these conveniences can be had, the worker must content himself with a jug of water, or a vessel with a rubber tube provided with a tap or a spring clip, the vessel being placed at some height, as on a chair standing on the table. Convenient collapsible rubber sinks with waste pipe can be had in Britain and probably in America. In photo-micrography as in all things we must "Cut our coat according to our cloth."

A set of flat "developing dishes" are necessary and not expensive. Two of these, the proper size for the plate to be used may be made of papier-maché or ebonite; they should be black. Two others, large enough to hold three or four of the plates may be of porcelain and should be white.

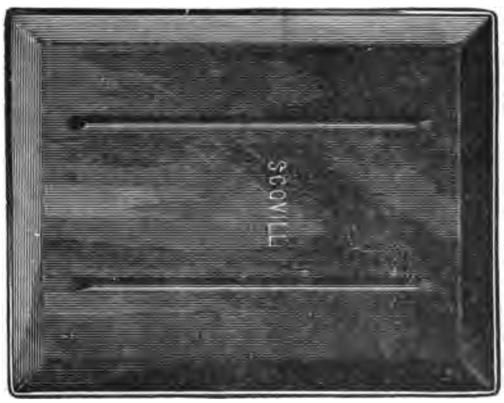


FIG. 18.—DEVELOPING TRAY.

Other dishes may be required for printing and other purposes; their uses will be seen as we proceed.

Some filter funnels; glass measures, say 10-oz., 2-oz. and 2 drams; scales and weights; a drying rack, Fig. 19; and, as a luxury, a washing trough, Fig. 20, may complete this branch of the outfit, which a few dollars will cover. For those who object to slightly stained fingers, a hook, Fig. 21, and a "pneumatic holder," Fig. 22, may be added.

The following apparatus will be required beyond the things already mentioned:

FIG. 19.—DRY-RACK.

FIG. 20.—WASH-TROUGH.

For all kinds of contact printing: Printing frames (see later).

For enlarging and reducing—which may be postponed till some practice has been gained in other works: A suitable camera, or arrangement of other cameras (see later); also a suitable photographic lens.

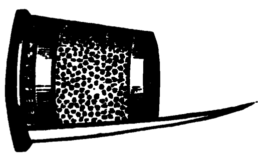


FIG. 21.—HOOK.

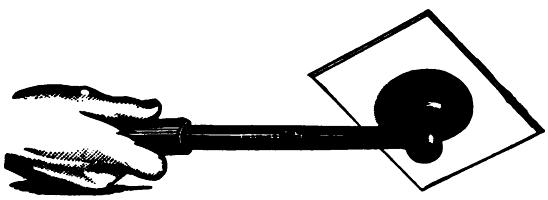


FIG. 22.—PNEUMATIC HOLDER.

A squeegee. Some glass plates or ebonite sheets a good deal larger than the largest negatives to be made direct.

The following articles are useful: A "Warnerke sensitometer;" a so-called "Matchless" gas burner, by which the gas can be lowered out of sight without entire extinction; this will be found vastly convenient in the dark room, Fig. 23.

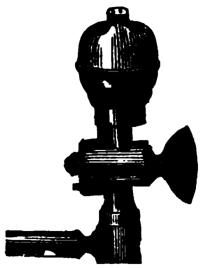


FIG. 23.—MATCHLESS BURNER.

FIG. 24.—SQUEEGEE.

The following is a list of chemicals which are certain to be required for development and other operations with gelatine-bromide dry plates:

Pyrogallol	1 ounce
* Citric acid	1 ounce
Sodic sulphite, ½ pound; or potassic meta bisulphite.	1 ounce
Sulphurous acid	1 ounce
Ammonic or potassic bromide	1 ounce
* Liquor ammonia, sp. gr. .880 (see later)	4 ounces
Potassic carbonate pure	4 ounces
* Sodic carbonate (crystals)	4 ounces
† Sodic hyposulphite	1 pound
* Potash alum	1 pound
* Hydrochloric acid (comml.; useful for cleaning things)	1 pound
Ammonic carbonate	4 ounces
Mercuric bichloride (*poison*)	4 ounces

For albumen paper printing on "ready sensitized" paper:

Auric terchloride ("chloride of gold," in sealed tube).	1 tube
Sodic acetate, or biborate ("borax")	1 ounce

For albumen paper not ready sensitized, in addition to the two last items:

Argentic nitrate.	1 ounce
Albumenized paper	a few quires

For printing on gelatino-chloride emulsion paper (" Aristotype"):

Ammonic sulpho-cyanide	1 ounce
Sodic sulphate	1 ounce

For printing on bromide paper, transferotype (Eastman), and for certain lantern-slide plátes:

Ferrous sulphate (protosulphate of iron)	½ pound
Potassic oxalate	1 pound
Acetic acid (glacial at 52 deg. F.)	1 ounce
* Sulphuric acid, good comm'l	1 ounce
* Sodic chloride (common salt)	1 pound
Pure talc or " French chalk " (for transferotyye)	1 ounce

For the wet plate collodion process either for negatives or for making lantern slides, a quantity of each of the following: Collodion iodized, or with separate iodizer; solution for cleaning glass plates; argentic nitrate; † distilled or pure rain water; ferrous sulphate in addition to the above, also acetic acid or nitric acid; sodic hyposulphite extra, or potassic cyanide.

For all negative processes: hard varnish, 5 ounces.

For all lantern slides: cold "crystal" varnish, 5 ounces.

These quantities are small, but will suffice for a start, and they are arranged as above so that the reader need not amass a large collection of chemicals for processes he does not propose to work.

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* These may be useful for all processes, and may be stocked in larger quantity.

† Necessary for almost all processes, and may be stocked in bulk.

CHAPTER VIII.

SOLUTIONS FOR PHOTOGRAPHIC OPERATIONS.

1st. To develop Gelatine Bromide Plates. The Pyrogallol or "Pyro" Solution:

Take

Sodic Sulphite........................	4 ounces	dissolve
Water to about........................	7 ounces	

Make slightly acid with sulphurous acid. Then pour into a a Commercial one ounce bottle of Pyro. Make up to nine ounces and filter.

Label the bottle "Pyro—10 per cent. 10 minims—1 grain pyro." Or better:

Take

Potassic Meta-Bisulphite*..................	1/2 ounce, avoir.
Water to about	7 ounces

This will dissolve easily, especially if the salt is pounded; then pour into a bottle of Pyro as above and label as above, having made up to nine ounces.

Or, lastly: just before using make a sufficient quantity of water acid with citric acid, and with that water make a solution of four grains of pyro to each ounce of acid water. This will constitute one-half of the measure of what will be called a "Normal Developer."

The writer uses and recommends the Potassic salt formula. But solutions known as "Sulpho-Pyrogallol" are sold, prepared more or less according to the formula of Mr. H. B. Berkeley, the originator of the compound, and these solutions are usually good. As before, 10 minims of the solution—1 grain of pyro.

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* A patent salt to be obtained from The Scovill & Adams Co.

Alkaline Solutions.

Take 1 ounce (chem.) Liquor ammonia fortiss. and dilute to 10 ounces with water. (As soon as any bottle of this solution of ammoniacal gas is opened, an equal bulk of water should be added, or better, water should be added till the hydrometer stands at .920.) In all cases the bottle must be kept closed when not in use, and the stopper of the bottle should be smeared with vaseline. Of course, after this dilution is effected, a double quantity of the solution will be required to represent the quantity given in terms of "liq. amm. fortiss."

The bottle containing ten ounces (1 oz. ammonia and nine of water) is to be labelled: "liq. amm., 10 per cent. 1 minim=1 minim ammonia."

Or,

Sodic Carbonate	1 ounce, avoir
Water to	9 ounces

Or,

Potassic Carbonate	1 ounce, avoir
Water to	9 ounces

Or,

Sodic Carbonate	½ ounce, avoir
Potassic "	½ ounce "
Water to	9 ounces

Label: "Carb. 10 per cent.—10 minims=1 grain carb."

Bromide Solution.

Potassic or ammonic bromide	1 ounce, avoir
Water to	9 ounces

Label: "Bromide 10 per cent.—10 minims=1 grain bromide."

Citrate Solution.

Sodic or potassic citrate (or half of each)	1 ounce, avoir
Water to	9 ounces

Label: "Citrate 10 per cent.—10 minims=1 grain citrate."

(Note: If chemical weights be used, the solutions are to be made up to 10 ounces, and labelled as above.)

FIXING SOLUTION.

Sodic hyposulphite .... 1 part
Water................ .... 4 parts to 5 parts

Made decidedly alkaline with a carbonate or with liq. amm.

CLEARING SOLUTION.

Concentrated solution of potash alum................ 1 pint
Citric acid .... 3 ounces
Hydrochloric acid.................................. 2 drams

If used before fixing the acids should be omitted.

REDUCING SOLUTION. No. 1. (Farmer.)

A. Potassic ferricyanide (red prussiate of potash)......10 grains
Water... 1 ounce

B. The ordinary "hypo" solution.

REDUCING SOLUTION. No. 2.

A. Perchloride of iron. (Druggist's tincture or saturated aqueous sol.)............... .... 2 drams
Hydrochloric acid.............................. 4 drams
Water to.................................... 20 ounces

B. Fresh hypo. solution

(This is probably superior to the Ferricyanide Reducer for lantern slides.)

INTENSIFYING SOLUTIONS.

a. Mercuric bichloride.............................. 1 part
Water... 20 parts
Hydrochloric acid.............................. .5 part

b. Sodic sulphite.................................. 1 part
Water ....8 to 10 parts

THE FERROUS OXALATE DEVELOPER.

A. Saturated solution at 60 deg. Fahr. of potassic oxalate,

B. 1 to 3 aqueous solution of Ferrous sulphate, to each pint of which latter is added sulphuric acid, 1 dram. (Water 3 parts; Iron 1 part, by weight).

Notes: A "saturated" solution of potassic oxalate will hold about 1 part by weight of the salt to 4 parts by weight of water.

The water may in each case be boiled to facilitate solution. The sulphuric acid is to be put into the water before the iron salt is added.

A and B will keep a long time if separate, but mixed they will not keep. For precautions in mixing see later.

Solutions For Printing Processes.

Sensitizing Bath For Albumenized Paper.

Argentic nitrate	40 to 65 grains
Water, distilled	1 ounce.

For the ammonio-nitrate process, and for full instructions on this entire subject, the reader is requested to consult "The Processes of Pure Photography," by Professor W. K. Burton, C. E., and the present writer. (New York: The Scovill & Adams Co.)

Toning Solutions For Albumenized Paper.

Sodic acetate	25 grains
Auric chloride (Terchloride of gold)	1 grain
Water	8 ounces

Used alkaline.

Toning Solution For Chloride Emulsion Paper.

See publication as above.

Fixing Solution For All Silver Printing Processes.

Hypo	1 part	made alkaline
Water	5 parts	

Solutions For Platinotype Printing.

a. A saturated solution of potassic oxalate. See above.
b. Hydrochloric acid, 1 part; water, 60 parts.
c. The same as *b.*

Solutions for developing lantern slide plates of various kinds will be found under the heading appropriate to them in Chap. XXII on lantern slides.

CHAPTER IX.

ON THE SELECTION OF PLATES.

THERE are not a few able photo-micrographers who assert that the wet collodion process is superior to the gelatine bromide process for photo-micrography. The writer is inclined to dispute this point, on the following grounds: The strongest argument of the advocates of wet collodion is that the deposited metal forming the image is in the wet process in a finer state of division than it can be in any gelatine process. The writer traverses this statement at the outset. The wet collodion process gives a more finely grained image than the *rapid* gelatine emulsion gives, certainly; but a gelatine emulsion made with certain precautions, and suitably developed, yields a metallic image quite as fine in grain as a wet collodion image, if not finer. But the gelatine emulsion for this must be very "slow," such as that used for the production of lantern slides in which the visible image approaches a *stain* more than a deposit in appearance. Moreover, the deposit in the most sensitive plate is so fine as to be incapable of producing the slightest granular effect by direct contact printing, or even after enlargement of the negative by photographic processes up to at least 4 diameters. And the writer is very strongly of opinion, having worked and thought out the matter very carefully, that both in theory and in practice no advantage whatever is gained, or can be expected to be gained, by "camera enlargement" of a negative, over a negative of the desired amplification produced directly with the micro-objective. If, for example, an ultimate magnification of 300 diameters is required, it will be better produced by direct amplification by an objective than by making a negative at "× 100," and enlarging 3 diameters in the camera; and an enlargement of 3 diameters, if properly managed will not,

with the coarsest grained image the writer ever saw produced by gelatine bromide emulsion, show any grain due to the coarseness of the image deposit. We have, in fact, seen negatives in most sensitive gelatine emulsion enlarged 5 diameters without the slightest appearance of grain. The argument for the wet-plate-and-camera-enlargement is that the ultimate result shows greater "penetrative" effect, that is to say that there is less apparent difference of sharpness in different planes of the object; the writer made a large series of experiments on diatoms, enlarging always to × 300, by direct micrographic means, and by camera enlargement from original negatives at 100 and 150 diameters; in every case the direct amplification was superior to the "enlarged" negative; and the plates used for the 100 and 150 diameter negatives were some wet, some very slow gelatine emulsion, while the negatives direct at 300 were in every case an exceedingly rapid gelatine emulsion. Thus much for practice, the theory is too intricate to follow here. At one time the writer thought that wet collodion would prove superior to gelatine emulsion, and he had got the length of producing a considerable number of wet plate negatives; but on using slow gelatine plates on the very same subject, which were chiefly flies' tongues, and minute hairs, he found the gelatine results were in every way equal to the collodion, while the ease and certainty of the former process were incomparably greater than with the latter, though the writer is well accustomed to the wet plate process.

But it is most important to make a wise selection of the gelatine plates to be used. Our objects may be divided into two great classes: the coarse and the delicate. When our objects are by nature coarse in detail, or when they are made actinically coarse by staining, we shall have no difficulty in getting contrast in our photographs; but when our objects are very minute, or composed of very minute details, or when they are so stained as to present very little contrast to the background and between each other, the affair is quite different, and a quite different class of plate is required. Where the danger is over-contrast rather than want of contrast, a "thin" plate, such as is commonly used in portraiture, is the best to use; but in cases of

great delicacy of detail or color—the real difficulties of photo-micrography—we require a plate thickly coated with an emulsion containing a handsome proportion of silver haloid. Moreover, with the first class of subject, over-exposure is less to be feared than the reverse, so that rapidity of emulsion is rather to be desired than avoided; while with delicate subjects the exposure, even with high powers, is never prolonged to inconvenience, except in very exceptional cases where oblique light is used. A good "portrait" plate, then, is recommended for the ordinary run of low power work, while for the higher flights of "critical images," bacteria and the like, a plate should be thickly coated, not too rapid, and capable of giving a plucky, or even a "hard," negative at will.

The two great factors in the late advances in photo-micrography have been: 1st. The introduction of rapid emulsion; 2d. "Color correct," or "orthochromatic" photography. (We omit for the present a third factor, which is optical in its nature). It may be asserted that the man who wishes to produce photo-micrographs of general utility, and still more, he who aspires to march anywhere near the van of the photo-micrographic army must master orthochromatic photography. There is no getting round this fact. The majority of the most useful objects are only to be rendered to the best advantage by color-correct plates, and a large number of objects can not be photographically rendered at all without such plates; and there are objects which will not be photographed until orthochromatic photography is perfected. The beginner should, therefore, provide himself with some orthochromatic plates for a start; as he becomes accustomed to their manipulation he is advised to orthochromatise his plates for himself, if he has facilities for drying plates. The subject of orthochromatics, though far too wide, as a whole, for full treatment in this book, will be treated as carefully and as fully as the author is able to treat it in a single chapter.

Under the heading of lantern-slides we shall give a description of the wet collodion process, which must suffice for the reader's present needs; the process given in that chapter will serve to produce negatives as well as positives. More

complete instructions will be found in "Processes of Pure Photography."

A dozen or two of ordinary portrait gelatine bromide plates, a dozen or two of very slow thickly-coated plates, and a dozen or two of "color-sensitive" plates, will form a sufficient stock for a beginner. If the reader is *au fait* in the wet collodion process, he will do well to try it in order to satisfy himself—as the writer did—as to the relative advantages of wet collodion and dry gelatine.

The greatest mistake that can be made is to change from one make of plate to another without very weighty reasons. The beginner, especially, should stick to one make of plate and work with it till he can work it well. There are few plates in the market that will not yield a perfect negative when properly used.

CHAPTER X.

THE CONDENSER AND BULL'S-EYE.—THEIR USE AND ABUSE.

In some almost classical books on the Microscope, the Condenser, Achromatic or otherwise, is passed over with little more than mere mention; its construction is described *en passant*, but it is easy to see that the writers placed little importance on, even if they understood, its use. It is by no means a long time since even the best microscopists were not wholly aware of the full advantage to be gained by a proper use of the condenser, and the author is informed that Mr. E. M. Nelson played a prominent part among the demonstrators of the scientific application of what is now admitted on all hands to be a matter almost as important as the objective itself.

The condenser, as before stated, is not intended merely to throw a blaze of light upon the object, and as it is necessary that the photo-micrographer should thoroughly understand the use of the condenser a diagram and some remarks are here given, which, it is hoped, will elucidate the matter, and still further remarks and diagrams will be found in a later chapter. (See p. 83)

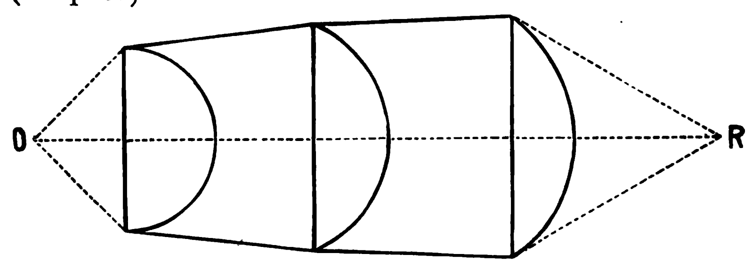


FIG. 25.—GENERAL OUTLINE OF ELEMENTS OF A CONDENSER.

The substage condenser is made to collect the pencils of light from the radiant *R*, and to focus these pencils on the

object O. The object-glass is also made to focus on O; and object-glass and condenser are working at their best when the object, or the critical plane of the object, lies in focus of both object-glass and condenser, *and then only*. The best resolution of any plane of an object can only be achieved when the object lies in the conjugate foci of objective, and condenser. But the focus of the condenser is not usually long enough to throw upon the object an image of the light large enough to cover evenly the field of the objective and so with low powers we have an image of the light only partially covering our field, and while scientifically speaking this is the true critical image of our object, still, as a rule, a photograph of an image so illuminated would be unsightly. Therefore we make a compromise in one of several ways; we sacrifice to some extent the accuracy of our critical, image in order to make a more sightly photograph. And often we may have so much resolving power "in hand," so to speak, that we may sacrifice some of it without losing any of the *necessary* resolution. Be it clearly understood that a critical image is really the image of the radiant with the object intercepting certain pencils of light; this is fact for all cases of axial transmitted light, but there are cases of oblique lighting and reflected lighting where the object itself becomes the radiant. At present we deal only with axial transmitted light.

We effect the compromise mentioned above in various ways, some better than others. The commonest way is to interpolate between light and condenser a bull's-eye which collects pencils of light from the radiant and transmits them parallel to each other into the condenser. The result of this is that the rays previously focused on a small area of the object are now spread evenly over the whole field, and if the bull's-eye is properly used in such a case there ought to be no falling off in the quality of the image. It is important to keep the bull's-eye at a good distance from the condenser, and the radiant must be at the focal point of the bull's-eye. This is the usual method of procedure with simple objects and low powers. The bull's-eye is sometimes used alone as a condenser, being turned with its convex side toward the radiant, and where an angle of not

more than 125 deg. is required, it answers fairly well in this capacity.

Another method of compromising has been much used by the writer for very low power work, and even under certain circumstances, for high power work; it answers as a makeshift for the low power work, but is not recommended for high power where, in fact, it is not necessary. The arrangement is shown in figure 26.

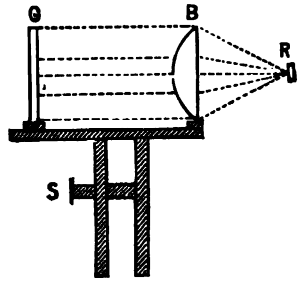


FIG. 26.

Here R is the radiant, B a bull's eye parallelizing R's rays upon a disc of very finely ground glass G, the bull's eye and disc being so fitted that they can be fixed as a whole piece of apparatus, in front of the radiant. Reference to figure 16 will explain the fitting of this to the front of the lantern; S, in figure 26, being a pinch screw by which the apparatus is fastened to the front. Here G becomes practically the radiant, and the writer hoped great things for this arrangement, until he found that he could not accurately focus the ground glass, even when oiled, on his object without getting an image of the grain of the ground glass, which was fatal, of course, to accurate focussing of this radiant. But for the lowest power work, where the angular aperture of the objective (as 3-inch, 4-inch, etc.) is very low, and where the use of a condenser is forbidden, this apparatus is strongly recommended and often used by the writer. It might appear that by using, in place of the plano convex B, a double convex, a small disc of very brilliant light would be obtained on G, the size regulated by sliding G to and from B, and that this small disc would be very valuable

for medium and high power work; but it is not so, for the difficulty of focusing the image of the ground glass again comes in. It may be worth while to try, in place of ground glass at *G*, a cell full of milk and water, as suggested by a friend of the writer.

There is still another method of obtaining, with a condenser alone, an evenly lighted field. This method consists in mis-focusing the condenser, but we need hardly point out at any great length the danger of this system. If, in Fig. 27, A be the object and C the condenser focused on A, as shown by

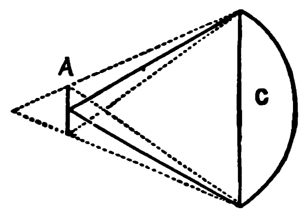


FIG. 27.

continuous lines, the image of the light seen with a low-power objective may be too small to cover the field; if we focus the condenser down (dotted lines), or up (interrupted lines), we shall get an even field of light, but our object will no longer fulfill our condition of being in the foci of condenser and objective at once, and so our image will be inferior. If we focus our condenser and *o. g.* both on our object, look down the tube without ocular, arrange our condenser aperture so as to file our *o. g.* with light, and *then* rack down our condenser, we shall see that our *o. g.* is no longer fully utilized; but on replacing the ocular we may find our field now evenly lighted. So that focusing down our condenser has entailed loss of aperture. If, by opening our condenser aperture by an iris or by a larger stop we can once more fill our objective with light, probably not much harm will be done to the quality of image by our racking down of the condenser; still the writer decidedly objects in practice to this system of mis-focusing, and recommends any other system in preference to this one.

To recapitulate: With low powers, where the image of the radient focused on the object does not sufficiently fill the field,

a bull's-eye may be placed between light and condenser, at a possible sacrifice. With high power objectives the image of the flame, focused as before, is usually large enough to illuminate the whole field without any bull's eye. With the lowest powers the condenser is usually and preferably omitted.

NOTE.—In very many cases it will be found convenient and advantageous to use an objective as substage condenser. The objective so used may have an aperture equal to or less than that of the objective used for the image projection. Those who have good objectives, but only poor condensers, may do well to adopt this system for all work. The writer, for purpose of experiment, had a mount made fitting his substage and taking his objectives; the addition of a small iris diaphragm made the apparatus complete. The results were so satisfactory that we would not hesitate to adopt this system entirely, were we not already in possession of Powell and Lealand's fine apochromatic, and Zeiss' achromatic condensers; the former of N. A. 1-4, the latter of N. A. 1, and capable of being used for quite low angles. For example, using in our substage as condenser an apochromatic o. g. of 16 mm. N. A. .30, we resolved with a 2 mm. o. g. P. angulatum, into white areas or black dots, with ease and at will. For ordinary photography of bacteria and the like we find this arrangement, or a similar one, not at all inferior to the use of expensive achromatic condensers.

CHAPTER XI.

THE USE OF THE EYE-PIECE OR OCULAR.—STOPS.—REFLECTIONS.

THE ocular in ordinary microscopy is an optical system whereby the aërial image produced by the objective is "taken up" and projected, magnified more or less, on the retina of the human eye. The ordinary Huyghenian ocular is made for this sole purpose; it is frequently made non-achromatic It is therefore not to be expected that an ordinary Huyghenian ocular, particularly one not achromatized, should project a perfect, or even a good image on a flat plate perhaps 30 inches distant from the spot for which the ocular was intended to work. The writer is, however, bound to accept as a fact in the experience of others what his own experiments have invariably failed to verify, viz.: that in some cases an ordinary microscope ocular does project on a screen, distant from the ocular from 20 to 40 inches, a true image, and that a photograph tolerably faithful to nature can be made of that projected image in the usual way. Certainly it is conceivable that by some accidental suitability of ocular to objective such a result may be obtained. The writer, therefore, does not gainsay the assertion that photo-micrographs of the highest quality and of difficult objects may be produced by the use of the ordinary achromatic eye-piece, but he does say that he has never produced nor ever seen any photo-micrographs that he could call first-rate obtained by the use of the common eye-piece sold with ordinary microscopes and used for ordinary observation. On the other hand microscopic objectives are not intended for projecting images upon screens several feet distant, but are constructed so that their best image falls somewhere between 6 and 12 inches up to the microscope tube; and, moreover, that image is intended to be "picked

up" carried on, modified, and in many cases and ways corrected by an ocular. Still the author has seen and produced micrographs without an ocular not easily to be surpassed.

One of the latest outcomes of optical science has been the construction by Herr Zeiss, of Jena, on formulæ by Dr. Abbe, of a series of oculars arranged for the purpose of projecting the image formed by the objective. The writer may as well state at once that he believes, and has good reason to believe, that in the use of the projection oculars, with other matters of different nature, will lie the future of scientific photo-micrography. In the author's experience these oculars have acted well with objectives made by makers other than Zeiss; for instance, they have been found to work satisfactorily with a 1-inch, a $\frac{1}{6}$, and a $\frac{1}{12}$ immersion, all by Swift of London; also fairly well with a $\frac{1}{20}$ by Reichert. It is matter for congratulation that the Zeiss (or Abbe) projection oculars are cheap, costing only about £2, or say $10 each. A chapter will be devoted to the apochromatic lenses and "compensating" and "projection" oculars made by Zeiss.

Undoubtedly an eye-piece of any kind, when it can be used without detriment to result, is a great convenience. The camera does not require to be so long; there is less danger of internal reflections, which must be sedulously avoided, as will presently be seen. But failing a projection ocular, or failing the necessary coincidence between projection ocular and objective, the balance of opinion and the balance of high-class results are probably in favor of the image projected directly upon the screen by the objective. The writer at all events is willing to commit himself to this opinion, and to recommend either a projection ocular or none.

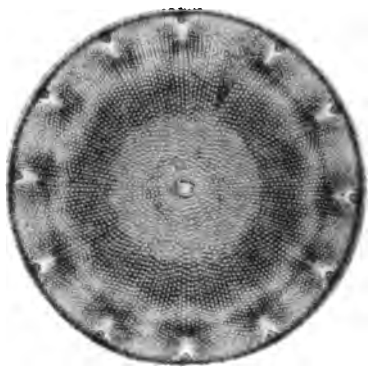
Amount of Magnification. To discuss this question we may adopt an arbitrary term: "Initial power." We propose to call the initial power of an objective the amount of magnification (in terms of diameters) given by the objective at 10 inches behind its posterior conjugate focus. (The distance, 10 inches, is about the distance for distinct normal vision, and is chosen for that reason.) A good objective will, as a rule, when properly used, stand a strain of magnification to ten times its initial power.

Thus: A lens of one inch focus gives at about 10 inches up the tube a magnification of 10 diameters; by whatever means we try to get from that lens a magnification of 100 diameters projected as a real image, it must be a good lens if it stands that strain without breaking down in definition or corrections. In fact none but the very best objectives will tolerate any such strain. By dint of exceedingly skillful manipulation such as only a few men can claim to have acquired, we have known specially fine objectives stand a stretch of their powers even greater than this, but the writer's own attempts in this direction have always been utter failures, and in the majority of cases six or seven times the initial power is ample to produce a faltering of the lens' capabilities. And this holds good whatever be the means adopted for increasing the magnifying power of the objective, whether long stretch of camera or high eye-piecing, or the two combined. Thus Zeiss makes two projection oculars for one series of lenses; the first ocular increases the magnification by "three times" and may be used without difficulty up to a stretch of about 30 inches from ocular to sensitive plate (giving a power about nine times the "initial power"); while the higher power projection ocular magnifying "six times" will at the same stretch break down the finest objectives, unless the skill of the operator be very great indeed, greater than the writer can claim, certainly.

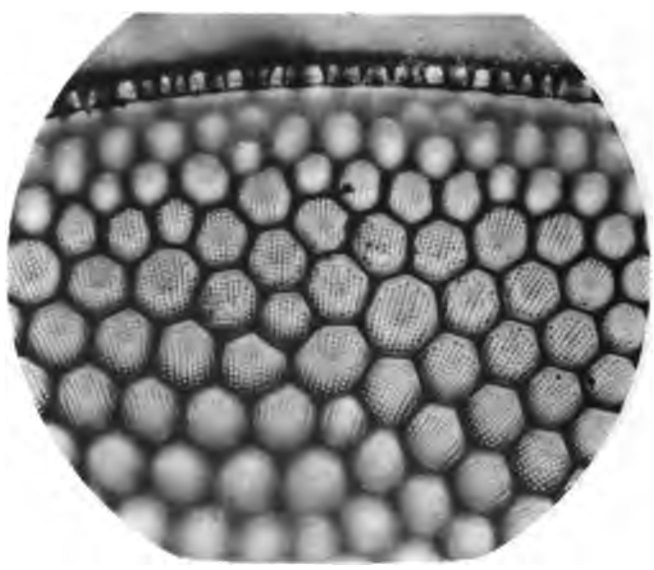
"*Stopping down*" *Objectives*. It is common to find at the back of objectives a cell or diaphragm constricting more or less the light-way from the objective to the eye or to the plate. So long as the "stops" do not cut off any pencils of light that otherwise would reach the plate or the retina no harm is done; but if the stops are used as a supposed means of reducing aberrations or incorrectnesses of the objective, a great deal of harm is done and a very foolish mistake made. By the time that the pencils of light have passed through the objective the mischief is done, if it is done at all, and a stop behind the objective may *hide*, but cannot possibly correct any errors. Whatever "stopping" is to be done should be done in front of the objective, that is to say in the condenser, or, failing a condenser, in the substage. If, therefore, the reader

illumination, "flares," and poor thin negatives with backgrounds dirty grey in place of dense black.

The apartment where microscopic work, visual or photographic, is going on, should be as nearly dark as possible.



No. 1.—A. Margaritaceus, × 150.



No. 2.—Triceratium, × 750.

PLATE II.

CHAPTER XII.

PROGRESSIVE EXAMPLES.

It is proposed in this chapter to give a few examples of operations for subjects presenting various degrees of difficulty; taking to start with the easiest class of object likely to be met with, and attacking it with the simplest apparatus likely to be required for any class of work.

Example 1. A subject presenting only light-obstruction, without very delicate marks or structure, and with just enough of color to give actinic contrast, thin and flat; to be photographed with a low power to a magnification not exceeding 20 diameters; no ocular nor condenser, direct illumination. Subject; a good *section of wood.* Objective: two inches focus or lower power. If an oil lamp provide the illumination the wick to be turned "broadside on."

Procedure: Having focused the object with objective and ordinary ocular, arrange the object and light carefully so that the whole field is evenly illuminated; attach the camera to the microscope, the ocular being entirely removed. Proceed to adjust the focus on the ground-glass of the camera; for this the microscope tube will require more or less racking in. In such work as this there is danger of the tube cutting off part of the field; a good wide tube is therefore an advantage. Notes: It is supposed that the reader has studied the foregoing instructions and diagrams with regard to means for preventing access of stray and reflected light to the sensitive plate. The leather cap seen at No. 11, on Fig. 16, is in the writer's practice placed on the end of the tube, and the camera is then pushed forward till the brass cap on the front passes into the leather cap 11, thus forming a light-tight junction.

In order to make sure that the lighting of the field is even, the best plan is to remove the ground-glass of the camera, and

to hold a few inches behind its late position a piece of white paper or cardboard. On this white surface the image is visibly projected, and uneven lighting easily detected.

In most cases the ground glass of the camera and the coarse adjustment of the microscope permit of sufficiently accurate focusing with very low powers, but a "Ramsden" eye-piece placed on the *plain* glass focus-screen may be found preferable in conjunction with the fine adjustment of the microscope. Often, however, where a good general appearance is wanted the unaided eye and ground glass are better in practice.

Our ground-glass disc illuminated by parallelized rays, as figured No. 26 on page 71 will be found most convenient for this class of work.

While the object is being examined in the microscope with the ocular, the part of the object occupying the centre of the field should be carefully noted; this point must occupy precisely the centre of the ground-glass where the camera is attached. If the apparatus is of the construction suggested on page 51, where the microscope and the light are fixed in their relationship to each other, and where the table bearing them rotates to a "stop" when the camera is about to be attached, it is important to note at the very first whether the centre of the object coincides precisely with the centre of the ground-glass when the image is seen on the ground-glass. The centre of the latter should be marked in pencil on the ground side of the glass; this may be done by drawing diagonals and describing a little circle round the intersection of the diagonals. The cardboard or other discs recommended on page 77, should have apertures corresponding in size to the sizes of plates to be used.

These remarks if carefully noted and acted upon will save trouble in future, and the image being focused on the ground-glass, the dark slide carrying the sensitive plate is inserted in its place, the light shut off, preferably by a shutter working very easily inside the camera, and all is ready for exposure, remarks on which are left for a later page.

Example No. 2. A subject similar to No. 1, but more finely marked and smaller, requiring more angular aperture, and still

practically colorless. Low power, narrow angle condenser, magnification about 30 diams. without ocular, 120 with projection ocular. Subject a flat diatom as *Arachnoidiscus Ehrenbergii*, or an Echinus Spine. Objective two-thirds inch or one inch; Achromatic condenser, front hemisphere removed.

Procedure: A. To centre the condenser—(*this step must be taken in every case when a substage condenser is to be used.*) Placing the pinhole cap on, or a pinhole diaphragm in, the condenser, examine with a low power objective and eye piece, working the substage centering screws. till the disc of light, (which may proceed from any radiant), occupies precisely the centre of the field. Remove pinhole stop or cap.

B. To centre the light. (*This also must be performed in every case.*) The condenser being centred as under "A," rack out and in the substage and the microscope tube with objective and low power eye-piece, until an image of the light is seen sharp in some part of the field. (The light may require to be moved in order to bring it upon the field.) With an oil lamp the wick should present its edge to the condenser. Move the light from side to side and up and down till its image falls directly in the centre of the field.

C. To focus objective and condenser on the object. Place the object on the stage so that it occupies the central position, focus the objective on the object and then rack the substage till *the image of the light is sharply focused across the object.* This is a suitable arrangement so far for obtaining the best possible image microscopically of a certain area and plane of the object. The nearer the light is to the substage, and the longer the focus of the condenser, the larger will be the sharp image of the radiant across the object.

D. To spread the light evenly over the field either a bull's-eye or a diffusing medium—as the ground-glass referred to above—must be placed between the light and the condenser. If the "ground-glass and bull's-eye" arrangement be used, the result is simply to transfer the radiant surface from the lamp to the ground-glass; if the bull's-eye alone be used the result is to fill the back of the condenser with parallel rays; and in order to get the most evenly lighted field the condenser will probably

require to be racked down more or less. The use of the bull's-eye is so important that diagrams and quotations from papers by Mr. E. M. Nelson, in the English *Mechanic*, 1884, shall be given in explanation. In the first place the light must be in the focus of the bull's-eye, and the latter is to be fixed so that the edge of the flame if a wick is used, or the surface of the lime if the limelight is used, is in the focus of the bull's-eye. In order to ascertain whether the bull's-eye and light are in proper relation to each other, Mr. Nelson recommends either that the eye be placed in the rays proceeding from the bull's-eye, or that a condensing lens be placed in the rays and the image thrown upon a white card there examined.

In fig. 28, *E* represents the edge of the flame, *P* the bull's-eye and *A* the image as it ought to be seen on the card.

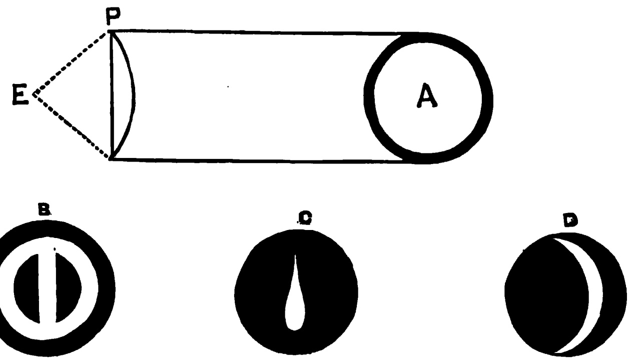


FIG. 28.

B represents the appearance when the bull's eye is too near the edge of the flame.

C represents the appearance when the bull's eye is too far away from the flame.

D shows the appearance when the bull's eye is focused, but out of centre.

In order to get the proper use of the bull's-eye, it should not be nearer to the substage than a distance of, say, 12 inches.

The same papers by Mr. Nelson contain information regarding the substage condenser, so useful that the author ventures to copy some further figures.

A (Fig. 29) shows a substage condenser and an objective focused on the same point, and the aperture of both equal and fully utilized. On looking down the microscope tube the lens will be seen filled with light as at *C*.

B shows a condenser and an objective still focused on one point, but having their apertures cut down by a stop in the condenser; the back lens, examined as before, will present the appearance of *D*.

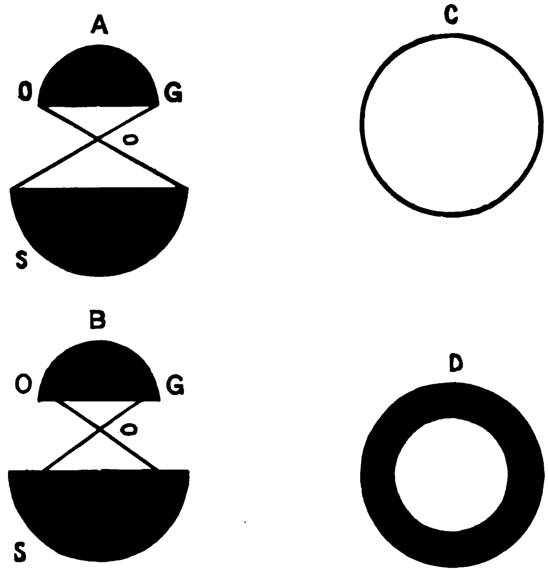


FIG. 29.

These remarks and quotations, though, perhaps, not in their proper order here, are to be *specially* noted in every case where a bull's-eye is used. The bull's-eye, as already stated, should be on a stand with a heavy base, and in order to focus the condenser when the bull's-eye is to be used, the following steps may be taken. The objective being focused, the condenser and light centered, the *edge* of the bull's-eye is advanced in front of the light and the image of the metal rim of the bull's-eye is focused on the object by means of the condenser. At the same time the worker must take care that the segment of

the circle of the bull's-eye seen on his field is vertically central, *i. e.*, the imaginary centres of bull's-eye and field should be in one line. This is difficult to explain, but will be understood on experiment. Lastly, when the field is illuminated, the bull's-eye being focused and in its place centrally, the worker is to look down his tube and compare what he sees with our figures on pages 82 and 83. If the entire area of the back combination is filled with light, we are utilizing all the aperture of our objective, and it may be said that, in many cases where it is desirable to utilize every fraction of aperture that our objective possesses, the use of the bull's-eye is to be recommended. In many cases the use of our entire aperture introduces photographic difficulties, but these must be overcome. If a photograph is wanted of the "general appearance" of an object, it is well to cut down the aperture much more than would be permissible where a scientific photographic representation is required. We are aware that this is heresy to some old workers.

Example No. 3.—A "critical image," with a low power, a condenser, no bull's eye. Subject: "Test hairs" on a blow-fly's proboscis. Objective: A two-thirds, one-half, or one-quarter inch of highest attainable aperture; this test for a one-quarter inch being, as a rule, too easy. Projection ocular used; magnification from 150 to 400 diameters. See Plate I, fig. 1.

A and *B*, centre condenser and light as before. *C*, for the two-thirds, or one-half, or four-tenths objective, the substage condenser may be used without its front hemisphere, unless with its front it has a very low angle, or unless it is not achromatic. Two things must always be observed with regard to the condenser; first, it must have sufficient angle to fill the objective; second, whatever its angle be, if its angle is greater than that of the objective, it must be stopped down till the angles are nearly equal. This time the object is focused carefully with the objective, and then the light is most carefully focused on the part of the "tongue" to be photographed. The hairs will now be seen more or less elongated, according as the correction of the objective happens to be more or less accurate.

Now come in the skill and experience of the worker, for the objective has now to be corrected for the thickness of the cover glass and the position of the test hairs with regard to the cover glass. The correction is to be accomplished by means of "screw collar," if the objective has one, or by length of tube, if the objective is without collar. We cannot instruct in this matter. The screw collar or the length of tube is to be altered gradually till the hair under observation is shown as *long* as it can be shown, as black also and as finely pointed. In critical image work it is better to choose one hair and confine the attention to that hair; if the object be not flat, of course other hairs will not be equally sharp, but we have nothing to do with that; our business is to get a perfect image of our one object. If we require the best general photo-micrograph of our "tongue" we must set about it by method No. 2.

The objective being corrected, and the image perfect as seen with the ordinary eye-piece, the latter is removed and the projection ocular substituted; the image is then projected first upon the ground glass of the camera. Assuming that a projection ocular of the type made by Zeiss is to be used, we have next to focus the diaphragm of this ocular upon our ground glass, where a round disc due to the diaphragm in the ocular will be seen.* This is easily done by observation, twisting round the moveable part of the ocular, where we shall find a scale and an index put there for the purpose. Next the image, having been carefully centred on the ground glass, is accurately focused on the plain glass prepared as suggested on page 53. Here again we can not instruct; it is a matter of experience to focus a difficult image. With objectives, other than apochromatic, fringes of color are usually found round the critical part of the image; very often, with ordinary objectives, the focus will be found correct when the colors seen are claret and green; but this depends on the correction for color given to the lens by the optician. The apochromatic lenses, in our

* If the image of the diaphragm as projected is larger, we may have to slew the camera a little in order to see the edge of the projected disc image.

experience, give little or no color which is not in the object, and we never, with these lenses, find fringes of color. But we find the focusing as easy with one glass as the other; it is only after development that the *superiority* of the apochromatic glasses shows itself unmistakably.

When we use "Ramsden" or "Aplanatic" focusing ocular color is often seen in the objects, but we must not attribute that to the objective. If this color is objected to, a very low-power ocular made by Zeiss, and called a "Searcher Eye-piece," may be sunk in a *plaque* of wood, that is to say, the eye-piece may be thrust through a hole in the wood to such a distance that when the wood occupies the place of the ground glass or sensitive plate, the diaphragm of the eye-piece occupies the critical plane where the image is to fall on the sensitive plate. Several holes may be bored in the plaque of wood, and the eye-piece may then be moved from hole to hole.

Under the next set of examples we may put a very large series of objects—always overlooking, for the present, the photographic difficulties of color to which an entire chapter is allotted—such objects, for instance, as the easier diatoms; physiological, histological and pathological subjects; insect structure and the larger bacteria where no minute structure is to be shown, as flagella. For all such subjects where the magnification required is from forty diameters upwards, the substage condenser with bull's-eye may be used, and the focus in such cases should be general rather than critical. Below forty diameters the writer avoids the use of a magnifying glass for focusing, believing that a better general focus is obtained without the Ramsden; he admits, however, that his eyesight is possibly abnormally sharp. As soon as the power used is sufficiently high to magnify the focused flame-image so as to make it cover the whole field to be photographed; *i. e.*, in all magnifications over say 400 diameters, the writer always dispenses with the bull's-eye. As already pointed out, the size of the flame-image on the field depends in the first place on the focus of the condenser, in the next place upon the combined power of objective and ocular. As the writer progresses in experience he uses the bull's-eye less and less in his work. In

fact he has of late discarded it almost entirely. Perhaps the best plan is to omit the bull's-eye and use a condenser of such focal length as to project on the object a sufficiently large image of the radiant.

Photo-micrography of deep objects, as many diatoms, is a vexed question which the writer prefers to leave undiscussed. The reader must judge for himself whether he is to get the best general appearance of his object, whether he prefers to resolve one plane without attention to any other plane, or whether he will be best suited by a compromise, that is, by a little resolution with fair general sharpness. One thing he need not attempt, viz.: to get perfect resolution on several planes simultaneously.

The achievements of the most difficult photo-micrography are vouchsafed only to the most careful and skillful operator. There is no secret in, nor any royal road to the photography of the flagellum of a microbe, or the "dots" on *P. angulatum.* Good optical appliances, absolute freedom from tremor, efficiency in centering, correcting and focusing, are the only secrets. Skill in these matters can only be acquired by long, earnest, unflagging study and practice. An occasional rush will not do for this work; it is necessary to give up to it the entire attention for the time being, and there is no use for any person to attempt this work at any odd moment, for failure is sure to result.

Above all we would counsel our reader to study the science of correcting his objectives by collar or tube; centering and focusing are mechanical, and follow definite and patent rules; "correction" is never alike for two objects, and is a matter of sheer accuracy of observation the highest quality a microscopist can possess.

In a later chapter we shall specify certain difficult and common test objects giving hints—and only hints—how the work may be attempted.

CHAPTER XIII.

EXPOSURE.

THERE is not a subject more important, nor any more difficult to deal with, than this one. We shall make it even more important in photo-micrography than it is in general photography, because we propose to advise the reader not to alter to any serious extent the constituents or proportions of his developing solution. It is a more difficult subject here than even in general photography, for whatever be the colors of the objects actually photographed in the latter branch, there is always a very large amount of reflected white light which to a vast extent lessens the difficulties arising from the colors of the objects themselves. Had we to photograph a landscape entirely by transmitted light, were such a thing possible, the result would be curious; in photo-micrography practically 99 per cent. of our light is transmitted, opaque objects being rarely photographed.

We may state at once that we do not approve of the system of trying to give rules for exposure; rules and tables doubtless assist the beginner at first but leave him helpless in the end. Moreover, it is futile to attempt to give rules, for it is impossible to take into account the most puzzling of all photo-micrographic conditions, that of color. If we worked only on colorless objects, we could easily give a most useful code of exposures, but no such state of thing obtains, a colorless object is very rare in photo-micrography. We propose rather to begin at the other end, and to inform our reader how to know after exposure where he has erred; and by this means he will not only very soon arrive at the proper exposure for the particular object in hand, but he will gain experience by every exposure he makes. By far the nearest approach to a scientific judgment of exposures that we know is the table

of Dr. E. C. Bousfield already alluded to (p. 14), as his table is copyright we do not, even with his permission, propose to use it here.

The factors on which exposure mainly depends, excluding from our consideration *color*, are

1. Illumination.
2. Magnification.

1. Illumination. We can no more lay down rules with regard to this than with regard to color. An oil lamp is the weakest light generally used, the lime light next, magnesium next, the electric light next, sunlight the most powerful. But all depends on how they are used; lime light properly burning and properly used may be much more active on our plate than diffused daylight. As we propose to consider here artificial light only, and specially the lights we know best, oil and lime, we need only say that the lime light may be from 10 to 50 times as powerful and as actinic as the best oil lamp.

The effect of the condenser properly used is astounding to the beginner, the bull's-eye sometimes increases and sometimes diminishes the force of the light.

The beginner after producing a negative will find it very difficult, even with the instructions to follow on later pages, to form a correct opinion as to whether his negative is over, under, or properly exposed. His best plan is probably to show his negative to some experienced photographer who will be able to give a certain amount of help as to the steps to be taken in future. But even the experienced photographer, and in some cases even the experienced photo-micrographer, will be at a loss to decide whether a negative is over or under exposed. In this case the only thing to be done is—if the prints are not satisfactory—to try a longer exposure and a shorter one. Exposures should be varied by geometrical rather than arithmetical progression; that is, if, for example, an exposure of 40 seconds is found to be wrong, it is well to try 20 or 80, or even 10 or 100 seconds rather than 35 or 50.

A weak background (*i. e.*, a ground grey in the negative and dirty white in the print) is a sure sign of one of three faults:

1. Under-exposure; 2. Reflected light inside the apparatus; 3. Too much light, or rather, too much angle not necessarily over-exposure (over-exposure, under certain conditions and to a certain degree, causes also grey backgrounds; but in this case, as we shall see later, the whole image is grey).

If we are dealing with a colored object we are practically compelled to disregard all circumstances except that of color. Color upsets every calculation of exposures that human ingenuity can devise. Reds and yellows sometimes cause us to increase our exposure a hundred fold, but there are reds which, being bluish (as eosin, a favorite stain with many for certain objects), upset all our previous calculations. Violets are, of course, as a rule, highly actinic, and require very brief exposures, but logwood, as an example, stains certain tissues to a violet so full of red that again we may be completely at sea in our exposure. The writer has daily experience of such puzzling conditions. Yellows, in like manner, are in certain objects practically almost chemical opacity, while in other cases their contrast with the white ground is so small as to render great the difficulty of differentiating between the yellow and pure white. A red, a violet, and a yellow may each be either very easy or almost impossible to render by ordinary photography; a mixture, such as a double stain of violet and red, is very often, without "color correct" or "orthochromatic" photography, a complete impossibility.

In view of conditions so common, yet so puzzling, we again submit that any table of, or rule for, exposure would be out of the question: what we may do, and propose to try to do, is to give guides by which the reader, on developing his negative, whatever the subject may have been, may be able to correct at next trial any error he may have made in his first exposure.

Appended to each of the illustrations of this book we have noted the exposure given by us in producing the negative, but even this attention on our part is only of minor value on account of our inability to gauge the quantity and quality of of the light actually reaching our sensitive plate.

CHAPTER XIV.

DEVELOPMENT OF GELATINE-BROMIDE PLATES.

Normal Developers.

A.—Pyro-Ammonia.

Pyrogallol	2 grains
Liq. Amm. .880	3 minims
Potassic or ammonic bromide	1 grain
Water to	1 ounce

B.—Pyro-Carbonate.

1.—Pyrogallol	3 grains
Sodic carbonate	12 grains
Water to	1 ounce

Or,

2.—Pyrogallol	3 grains
Potassic carbonate	12 grains
Water to	1 ounce

Or,

3.—Pyrogallol	3 grains
Sodic carbonate	6 grains
Potassic carbonate	6 grains
Water to	1 ounce

Notes.—The reader is referred to Chapter VIII for hints as to method of "stocking" the above reagents. The stock solutions there formulated are all so-called "10 per cent. solutions," and in each case a grain or a minim may be obtained by taking ten minims of the stock solution.

Thus to make the Normal Pyro-Ammonia Developer we take of

Stock pyro solution	20 minims
Stock Ammonia	30 minims
Stock Bromide	10 minims

and make up with water to one ounce.

To make the Normal Pyro-Carbonate Developer No. 3:

Stock Pyro Solution	30 minims
Sodic and Potassic Carbonate Solution	120 minims (=2 drams).
Bromide	None.

Make up with water to one ounce. (No account is taken of the chemicals used merely to preserve the pyro.)

Normal Developer *C.* Ferrous Oxalate.

Take of the saturated solution of

Potasssic oxalate	4 parts
Ferrous sulphate	1 part

Be careful to pour the Ferrous Sulphate Solution into the Potassic Oxalate and not *vice versa.*

(Note.—The writer does not recommend the Ferrous Oxalate Developer for ordinary photo-micrographic work. This is not denying that it is excellent in some hands and for some kinds of subject. The reader is advised to try the effect for himself; as a general developer it has some recommendations.)

The plate after exposure is, in non-actinic light, (see pp. 55 and 56,) placed film upwards in a black developing tray, and the developing solution is deftly swept over it; the developer must not be poured upon one spot but "swished" with a side motion all over the plate, so that as far as possible the plate may be all wetted at once. Some workers prefer to soak the plate, till the gelatine is all wet, in plain water before applying the developer; this procedure does no harm if air bubbles that may form are removed with a clean brush or finger. In all cases the inexpert must be prepared for air bubbles and remove them if they occur.

In a certain number of seconds the image ought to begin to appear. The first thing that regulates the time required for this first appearance is the quality or treatment of the gelatine used in the emulsion; this factor need not be taken into much account. But the important matter is to observe the quality of the image at the time of its first appearance, and still more is it important to note most carefully the pace at which the details follow each other. As a rule an overexposed plate will show some of the details before an underexposed

plate of the same batch would do so. If with any of our "Normal Developers" no image at all is visible after thirty seconds, the plate may be put down as underexposed. The image appears in the following order of rapidity with our three Normal Developers: 1st Pyro-Ammonia; 2nd Pyro-Carbonate; 3d Ferrous Oxalate. This is to be taken as a general rule in comparing the Carbonate with the Oxalate developer. Bromide always slows the appearance, and also the acquisition of density and detail, of the image and free bromide in the developer has a much greater apparent effect on the carbonate and ferrous developers than on the ammonia developer. Half a grain of bromide in the carbonate or ferrous developer has *at least* as much retarding effect as a grain in the ammonia developer. Bromide restrains both detail and density, but luckily it restrains detail more than density. The chief use of free bromide in the developer is to give us time to watch progress and to stop progress at the proper moment, but bromide is absolutely necessary to prevent fog with certain plates used with the ammonia developer. In the case of the carbonates the carbonic acid evolved acts as a restrainer and retarder; in the case of the ferrous oxalate, ferric bromide is formed in considerable quantity, and restrains and retards development. Hence a ferrous oxalate developer used over and over again works each time more slowly and more feebly than the time before. We deprecate the repeated use of the same dose of pyro-developer; but repeated use of one dose of ferrous oxalate is quite permissible up to a point which will easily be known by muddiness of the solution, and slowness of its action.

If the image starts about 10 or 15 seconds after the developer is applied to the plate, we must be prepared for overexposure of the high lights at least. With subjects presenting violent contrasts of density or color-actinism, we are almost bound to over-expose the high lights; but with ordinary subjects the image, if it appears at all in 15 seconds, should show only the highest lights at that stage; and the half tones of a properly exposed plate will follow the high lights without any lagging or apparent reluctance. In fact, the development should proceed steadily, without stoppage and without precipitancy from start to finish, so far as detail is concerned.

The details that first appear under any of our normal developers must be most carefully scrutinized, because upon their appearance we shall to a great extent base our judgment of exposure. If the first details are pale gray and are hurriedly followed by others almost equally gray the plate is over-exposed; if the first details rapidly become black, while other details are either pale gray or invisible, the plate is certainly under-exposed. If the whole plate become very quickly gray over-exposure is certain; if the whole plate become dense black, or dense black and dark gray, a less degree of over-exposure is the probable cause.

Experience, and a certain amount of allowance for the nature of the subject, are both necessary in judging of exposure by observation of the appearances during development; but when experience has been gained, and a variety of subjects photographed, the worker will be able very accurately to judge where and how much he has erred—if he has erred—in exposure. But two things are settled: An image homogeneous in color all over is an over-exposed image; an image which is white in any part when development is complete is an under-exposed image, unless we have a subject requiring absolute blackness in our print, such, for instance, as a "dark-ground" subject. If some part of our object be nearly opaque or highly non-actinic in color, as many pathological and physiological red stains, we have but two courses open to us. 1st. To deliberately over-expose the high lights or actinic colors to such an extent as will allow development of the opaque or non-actinic parts. Very often this method is unexpectedly successful, the high lights not being so much overexposed as might have been feared; or 2nd. We must use a color correct plate, cutting off, if necessary, the over-actinic rays by suitable screens. (See chapter XVI.)

Another matter resting chiefly on experience, and almost impossible to treat usefully in a book, is the amount of development required. In most cases when details are all "up," not necessarily distinguishable but at least developed, the density of the negative after fixation would not be sufficient to yield good prints by any of our usual processes. Now in

the course of development as a rule sufficient bromide is evolved (beyond the soluble free bromide we put into the developer), to greatly retard if not to arrest the growth of detail and density. Where the subject itself presents violent contrasts it is well to expose to such an extent that the first dose of developer shall reveal *all* detail without undue density in any part. Where the high lights or actinic colors are, as above advised, deliberately over-exposed in such subjects, the action known to photographers as the "reversing action of light" comes in, and these over-exposed high lights in place of being densely black in the negatives, undergo the reversing action and refuse to develop density. This, of course, suits us admirably in the cases under consideration—of violent contrasts. But if the subject be an ordinary one without violent contrasts, or if we require as nearly as possible a black and white rendering of such objects as diatoms, then we find that when detail is all "up" density is insufficient, and we reinforce our developer with alkali. In the case of the carbonates, *time* will produce the desired effect, because though retarders are being evolved there is no volatilization of the alkali; but with ammonia as the alkali, not only is fresh bromide being evolved but the original alkali is evaporating, so we generally add about 1½ minim of ammonia (15 minims of our 10 per cent.) to each ounce of developer as soon as there appears to be a halting in the acquisition of detail or density.

To know when to stop development is a very serious matter. Many so-called rules have been laid down, and many hints given on the point, but we have never found any such rule or hint to cover many cases. The image is not fully developed as a rule until some part of it is visible from the back of the plate, any further examination of the back may inform us of the nature of the gelatine, of the nature of our subject, of the degree to which the emulsion has been "cooked," but that is all. If we have a standard non-actinic light, through the colored medium guarding which we can see the flame through the plate, we shall by experience come to judge very fairly whether a plate of a batch we know is sufficiently developed. The flame should be barely discernable as to shape through

the dark parts of the negative; the whole plate should look as if it would be a *very great deal too dark* but for the fixing operation. But it must by no means be opaque nor equally dark all over, nor must there be any part where the shape of the flame is clearly visible, as through clear glass. *Looking at* the face (film) of the plate, some parts should seem quite black, others dark-gray, others (the shadows) paler gray but not white. Practice alone, and as before consideration of the various qualities of various subjects, can ever teach us what is perhaps our most difficult lesson next to proper exposure, viz.: when to stop development.

In cases of error in exposure, if the error is but slight we can almost always make our negative as good as if we had exposed correctly. And further, there are certain subjects which cannot by exposure alone without a little "dodging" in after processes be rendered to the best advantage. We have suggested a method of treatment for subjects presenting violent contrasts. We presently shall touch on other abnormal subjects.

But we must now mention another system of development which has marked advantages for the beginner; its chief disadvantage being that in using it we have not the same useful guides to judgment of exposure. This system is usually called slow development, and as a rule the carbonates are the alkalis used. The difference consists simply in starting development with a very weak developing solution, and adding the reagents if necessary little by little till the full normal dose is reached or the full effect produced. Thus we may start with pyro, 2 grains; bromide, 1 grain; ammonia, 1 minim; and, after (say) 3 minutes add a minim more of ammonia, and so on for a space of from 20 minutes upwards, or we may start with only 5 or 6 grains of the combined carbonates and pursue a similar course. The writer has never in ordinary photography found the slightest benefit to arise from such a prolongation of development, unless it be that in certain cases more contrast of light and shade is obtained by the slow method. The tyro has perhaps more time to make up his mind when to stop development, but in the system recommended by us he has cer-

tainly 3 minutes, probably 4 or 5, to examine progress, and he can hardly want more; further, by the slow process 15 or 20 minutes will be needed simply perhaps to find out that another exposure is required. Those, however, who lean towards slow development may refer to any of the Scovill series of photographic books, where they will find full details.

Abnormal Development.

It has been said that if the error in exposure has been but trifling a perfect negative may still be made. It is better in most cases to make a fresh exposure, but this proceeding may not at all times suit the worker, and further it is well to gain a little mastery over, and tact in, manipulation of the developer.

If appearances cited above show that the plate has certainly been underexposed, the developer should at once be thrown away and the plate washed. Thereafter a fresh developer is applied containing less pyro and bromide. Thus: Pyro 1 to 1½ grains. Bromide ½ a grain. Ammonia as before. Or water may be added to the first developer which is to be immediately reinforced with alkali. If the plate is known before development to be underexposed to a considerable extent, it may be soaked in the alkali and water of the developer alone for a couple of minutes, the pyro and a modified quantity of bromide to be added thereafter. But an underexposed plate as a rule is useless, no matter what we do with it.

With overexposure the matter is different, for a plate grossly overexposed can be saved if it is taken in time. The difficulty is to catch it in time and to apply the cure in time. Bromide certainly restrains detail but unfortunately it also keeps back density, and in a severely overexposed plate density of the high lights is the very thing most lacking. If the overexposure be only enough to make the plate *very black* all over, or as is the usual case, very black and dark grey, the simplest cure is to add water to the developer and to stop development earlier than if the plate were properly exposed. But if the overexposure has been sufficient to make the image grey all over, the best plan is to watch carefully till every detail seems out and then instantly to flood the plate with water containing, for

every three grains or one minim of alkali in the developer, from two to four grains of sodic or potassic, or sodic and potassic, citrate. (See page 62.) This immediately stops all further development of detail, but does not seem to affect density which is gained as follows: Add to the original developer, or to a freshly made one, two to four grains of citrate for each minim of ammonia or for every three grains of carbonate, pour away the water and citrate on the plate and apply the modified developer for a minute or two. Then add to the developer a brisk dose of alkali, say two minims of ammonia, and continue development till sufficient density is attained.

The carbonates may be restrained so easily and so forcibly with bromide, that perhaps the simplest way when developing with them is to add (say) one grain of bromide for each ounce of developer. Water alone added to the carbonate developer sometimes suffices to overcome moderate overexposure.

When the subject dealt with is by nature wanting in contrast it will be found useful to develop with an ordinary developer until all detail is up, and then to add citrate to the developer finishing as above with the brisk dose of ammonia.

The citrate was suggested by Mr. Watmouth Webster, now of Chester, Eng., and from its action in stopping detail but not density in development will be found very useful.

We have in this chapter formulated for one ounce of developer only; this quantity will develop a quarter-plate; two ounces a half-plate or 7x5, four ounces a 10x8 plate; but the the beginner is advised to double these quantities till he has become adept in evenly and quickly flooding his plate.

During development the plate should be constantly shielded from light even of the non-actinic lamp, being uncovered only at the time and for the purpose of scrutiny.

It may be well to recapitulate certain points of this chapter referring to certain appearances shown by a plate soon after the image has started to appear in the developer, normal as on pages 91 and 92.

Refusal to appear for one minute, or appearance in highest lights only, bespeaks utter underexposure.

High lights grey, shadows wanting—severe underexposure.

High lights dense black, shadows dirty grey—under-exposure.

High lights appear after fifteen to thirty seconds, grey at first, gradually darkening, shadows creeping up steadily all the time; finally high lights black and shadows ranging from pale to dark grey—correct.

High lights rapidly followed by shadows, the whole rapidly gaining great blackness and density—overexposure.

High lights and shadows appearing almost immediately and simultaneously, the whole turning rapidly gray and remaining so—great overexposure.

Instant flashing out of the whole image, all remaining a very pale smokey grey—enormous overexposure.

THE HYDROQUINONE DEVELOPER.*

This system of development has of late been greatly elaborated and improved, especially since it was found feasible to use hydroquinone in conjunction with the hydrate or caustic alkalis without damage to the film. Whether or not this is destined to be the standard developer of the future, we are confident in stating that it is a very fine developer at present. Indeed, on account of the ease with which almost any amount of density may be obtained without injury to the shadows, it is probably the best developer for photo-micrographic negatives. A further advantage is that this developer can be used without the presence of soluble bromides. We give a formula due to Messrs. Thomas & Co., of London; though containing a heavy dose of hydroquinone, it is not really expensive, as one dose of the developing solution may be used for three, four or even more plates. The formula stands thus:

a.	Sodic sulphite	1 ounce
	Citric acid	30 grains
	Amm. Bromide	10 grains
	Water to	10 ounces
	Dissolve and add hydroquinone	80 grains

* It is to be hoped that hydroquinone will soon be universally called by its shorter and systematic name: "Quinol."

b. Sodic hydrate "caustic soda"	80 grains
Water (that has been boiled)	10 ounces

The developer consists of equal parts of *a* and *b*.

The action of this developer is on the whole more gradual than that of a pyro-ammonia developer; the density varies chiefly as the exposure, and the shadows have a tendency to develop more slowly and with greater clearness than when pyro is used.

The carbonates may also be used with hydroquinone, but such a developer is much less energetic than the above.

The writer frequently uses potassic meta-bisulphite in place of the citric acid and in less quantity.

Potassic hydrate is as good as sodic, or better. It is well for the beginner to use the above solution somewhat diluted, say with an equal measure of water.

CHAPTER XV.

OPERATIONS FOLLOWING DEVELOPMENT.

Fixing, Clearing, Intensification, Reduction.

After development is judged to be complete the plate is to be carefully washed by non-actinic light under a tap for a couple of minutes or in a few changes of water. It may then be placed in a saturated solution of common alum; but except in cases where plates have a tendency to frill, this is not necessary. The plate is then "fixed" in a solution of sodic hyposulphite made alkaline. (See page 63.) The plate is to remain in the "hypo" solution not only till the white (unaltered argentic bromide) has disappeared from the back, but a considerable time longer. If the plate is removed as soon as the white has gone, it will deteriorate to a certainty after a time. After fixation, the plate must be very thoroughly washed, preferably under a rose tap, for 10 minutes, or in one of the washing-machines sold for the purpose. Several hours are necessary in the latter case. After the hypo is undoubtedly removed the plate may be "cleared" in the acid alum solution formulated on page 63. In this it may remain for about 5 minutes or longer. It is thereafter to be thoroughly washed, and racked to dry. The beginner at all events is recommended to make a print from his negative before he ventures upon any other step he may think advisable. The negative should be shown to an expert photographer, who will instantly say if there has been any serious error of treatment.

If the negative is "thin" or pale all over and wanting in contrast, yielding on albumenized paper a "washed-out" looking print, all gray and no black, intensification may be tried.

To Intensify.

The negative being above suspicion of hypo is soaked in a flat dish in the solution of mercuric bichloride and acid given on page 63. When the film is as pale gray as it will become, it is well washed and placed in the solution *b*, given on the same page. Here it will very quickly turn black or brown; but it must be left in the sodic sulphite till it is dark when seen from the back as well as from the front. It is then washed, and will be found to have gained greatly in density and printing quality.

There are many other methods of intensifying for which we refer the reader to the photographic literature of the day. We have given the one we prefer to all others, especially for photomicrography. As a rule, however, intensification is to be avoided, for it is not only ticklish to perform but doubtful—under conditions not precisely established—as to its permanence.

If the finished negative is too dense, especially if the shadows are clogged, we may have recourse to "reduction," which does not present the same difficulties as intensification.

Reduction.

To Mr. Howard Farmer we are indebted for a very simple and effective system of reducing. (See page 63.)

Soak the plate, carefully freed from acid after the acid alum bath, in solution B, for 3 minutes. Put into a cup a few drops of the solution A, and pour the hypo-solution into the same cup, then returning the mixture to the dish holding the plate. Reduction will at once begin and its progress must be watched. If the action cease before sufficient effect is produced add more of A. When finished wash well and dry. The Reducer No. 2, given on page 63, may be used. The plate is soaked in A till a gray film more or less marked seems to cover the image; the plate is then washed and placed in solution B.

Varnishing.

If a large number of prints are likely to be wanted from a negative it is well to varnish with a spirituous solution of shel-

lac, or better with one of the good negative varnishes sold for the purpose. The instructions as to heating the plate are to be carefully followed. Plain collodion makes a very good and usually sufficient protection for the film. What we have to avoid is damp, and of course our negatives must not be scratched. The only objection to varnish is that if appreciably thick it may prevent absolute contact for contact printing, perfect "sharpness" being important in photo-micrography.

A good negative presents gradations from nearly opaque highest lights, to clear but well marked shadow detail. The shape of a candle flame should be discernible with difficulty through the very densest parts of the negative. There should be *no clear glass*, but *some* detail everywhere. The higher lights as well as the deeper shadows should show detail. These remarks hold good for nearly all kinds of subject, but there are exceptions.

If in a negative we find dense lights in close juxtaposition with clear shadows the negative is underexposed, unless the subject is for "black and white" rendering.

If any part is absolutely opaque and (1) some parts are quite clear, underexposure, or (2) all other parts too dense, overexposure, is the probable cause. If the negative is grey all over, nothing in it approaching opacity—overexposure, or underdevelopment.

If the negative is clear nearly all over, underexposure is certain to be the fault.

Frilling and blistering are not often met with now-a-days. If a plate frills before it goes into the fixing solution it is a bad look out for that batch; frequently the carbonates if long applied in the developer cause frilling or isolation of the whole film; ammonia has not this tendency. If the blistering or frilling appear on first washing after the hypo, a cure will usually be found in soaking the plates straight from the hypo in a tray of common salt and water, say one part to twenty. Too strong hypo solution may cause blisters.

Fog, which is easily recognized when seen, must be traced to its source. If the parts of the plate protected during exposure, as by the paper mask, or by the rebates or corners of

[illegible] and fogged, either the plate [illegible] light of the operating room [illegible] the plates are quite clear, we [illegible] that to reflection inside the [illegible] negative can stray light [illegible] are the [illegible] or the streak [illegible] for the leakage. A hole [illegible] streak than one of the same size.

[illegible] very frequent cause of failure, [illegible] are not difficult to recognize, [illegible]

[illegible] plates are liable, [illegible] However [illegible] negatives not [illegible]

[illegible] size, called "Pinholes" [illegible] to the film, these spots have [illegible] condition, usually [illegible] plate must be dusted [illegible] put into the slide.

No. 1.—"Taste-buds" in Tongue, × 100.

No. 2.—Typhoid Bacilli in Intestine, × 750.

PLATE III.

CHAPTER XVI.

COLOR-CORRECT PHOTOGRAPHY.

"Ortho-Chromatic," or as we prefer to call it, "Color-Correct" Photography, is one of the latest important improvements in our science. It may be well to explain the rationale of this modification of common processes, and the reader is begged to study carefully our introductory remarks to this chapter.

It has been probably remarked by all observant people that while the colors yellow, bright red, and certain greens appear to the eye the most luminous colors, they are in photography rendered as dark, or at least as below the average grade of light, in the landscape, portrait, or copy of a colored drawing. On the other hand the indigo and violet colors of an object seen in the usual way appear to the eye dark or at least subdued tints; while these colors, when portrayed in the monochrome of photography, are represented as high lights. This has always been a serious objection to photographic rendering of many objects, notably of painted pictures, and to a considerable extent of landscape with foliage and sky effects. It is evidently a very serious objection to photo-micrography if we render an object, stained (say) with the dark violet of logwood and the bright red of eosine or magenta, the very opposite of what it really is visually; viz.: bright in the print where the object is dark violet, and dark in the print where in the section there is a fine glittering red. Further, if we have an object entirely red or entirely yellow but in gradations of red or yellow, it is most annoying to get a print of a homogeneous blackness, simply because our plate is practically insensitive to even the palest of the red or yellow. The difficulty also is great with an ordinary plate where we have either a

dense yellow object on a pure white ground,or a very pale yellow or pink of such a nature that the contrast between object and ground is very small. Color-correct photography helps us out of all these troubles and many besides; and it may be stated once more, as it has been stated by the writer on former occasions, that no branch of photography has been so much benefitted by "ortho-chromatics" as photo-micrography, and that in color-correct photography lies the future of photo-micrography. The writer has lately produced such renderings of double stained pathological subjects, prepared without regard to photographic requirements, as a few years ago neither he nor any other person would have been mad enough to attempt.

The advances that up to this date have been made in ortho-chromatics may be summed up briefly in the statement that our plates have been rendered more sensitive to yellow-greens, yellows, oranges and reds than they could be made formerly, and less proportionately sensitive to blue-greens, indigos, blues and violets. Plates have even been prepared as sensitive to yellow as to blue; but our usual procedure is to make a plate more sensitive to yellows, etc., than an ordinary plate, and a little less sensitive to violets and blues, and to assist the action when necessary by calling off more or less of the blue and violet by means of yellow "screens." By this method we have more command over our results than if our plates were as sensitive to yellow as to blue; indeed, if we carried the sensitiveness too far into the red end of the spectrum, we should often have to cut off some of our yellow rays, and we should have great difficulty in finding a suitable light whereby to develop our plates. Still, for a few subjects, a greater sensitiveness to red would be a great boon, though developing difficulties would multiply.

In Britain, at least, color-correct gelatine bromide plates may be bought; as a rule, they keep quite well for a few weeks, but we prefer to use them within a few days. Mr. B. J. Edwards, working under the "Tailfer-Clayton" patent, produces plates orthochromatized by an eosin process; Mr. J. R. Gotz trades in plates sent from Germany by Vogel and

Obernetter. The best color-correct plates for photo-micrography we have ever used were produced by Mr. Edwards for copying purposes. Where sensitiveness to certain regions of the red is required, the "azaline" plates of Obernetter are, perhaps, the best in the market; but "cyanin"-stained plates are the best of all for reds.

The photo-micrographer who has time and a good drying cupboard may quite easily orthochromatize his own plates. An emulsion should be chosen capable of giving ample density, not very rapid, and not containing more than 3 parts of iodide to 100 of bromide. The writer has tried, perhaps, every published process of any promise for "staining" his plates, but finds none so simple or so effective as a process lately promulgated by the talented Mr. Ives, of Philadelphia. The dyes suggested by Mr. Ives are erythrosin and cyanin. The latter seems to sensitize for reds more than any aniline we have tried, but the operations must be carried out practically in total darkness. The erythrosin or cyanin may be used as follows:

Take of the dye	1 grain
Absolute alcohol	4 ounces

Soak the plate in this for one minute, allow to dry in total darkness. This will not take long. Then place the plate face upwards in a black tray and cover the tray with another tray or flat cover having a hole in the top into which is let a piece of tubing. Connect the tubing with the water tap and wash the plate in the covered tray for five to ten minutes. In very subdued red light, or in darkness, convey the plate to the drying press; when dry it is ready for use. The drying-box or press must be properly constructed for passing a constant current of dry air; details of such presses will be found in "The Processes of Pure Photography" (Scovill & Adams Company).

A book as long as the whole of this one would be required to do full justice to the processes of color-correct photography. We have to allow for such wide variations of color, and there are so many different methods available for meeting our various

color difficulties, that we can only give the outlines of the principles upon which we work. In the majority of cases a color-correct plate is almost useless unless we use in conjunction with it a "screen," but it must be remembered that if we are using an oil light, and particularly a paraffin lamp without camphor in the paraffin, our light is yellow, and to a considerable extent acts precisely as a yellow screen would do. It is necessary to have several yellow screens of different tints, and it is well to have also one or two screens of blue, also of varying tints. A glass of a color known as "signal green" will be found useful for pale reds of which eosin stains are types. The colored glasses called "screens" ought to have their sides perfectly parallel, (ought to be what opticians call "worked,") but unless the screens are to be used in some critical position in the light rays, as for example *close* behind the condenser, we do not insist upon this perfection. We do not find that it matters in the least where the screen is placed so long as it is between the light and the object, and so long as no light reaches the object except such as passes through the screen. The colored glass may be put in a holder about midway between the light and the condenser. If, as in some cases, the screen is screwed into a part of the mounting of the condenser (in which position it is often called a "light-modifier"), then it ought to be "worked" glass. A set of most useful screens can be made by mixing *aurantia* with collodion, and three screens may advantageously be made in this way by mixing the aurantia in three different proportions, about one grain of dye being first dissolved in one ounce of alcohol. The collodion may then be poured upon a glass plate, which has been previously thoroughly cleaned, and then rubbed all over with French chalk (powdered talc), the chalk being apparently all removed with a clean dry cloth. If desired, the collodion, which must be in an even film, may be, after drying stripped from the plate and used as a film, or the edges may be varnished, and the film left on the glass. One screen should be of the very palest color, the other two progressively darker. At need any two, or all three, may be used together. We are indebted to Mr. C. H. Bothamley for the suggestion of aurantia.

Mr. Wellington recommends an alcoholic solution of turmeric, and a solution of picric acid will also be found to be of great service. In any case the screens must, when tested by aid of a spectroscope, cut off some portion more or less of the violet and blue of the spectrum.

In cases where we have blue or violet lacking actinic contrast with the white of the background, or likely to be over-exposed before other colors (as yellow or red) can be sufficiently exposed, we cut off some blue or violet by use of our screen, and the paler is our violet or blue the darker must be our screen. But if our violet be very dark, and more particularly if it be a reddish violet, such as logwood shows at times, we shall get a better result in presence of a red or yellow-brown contrast stain, if the latter be pale, by omitting the screen entirely, for the depth of the violet amounts in practice to so much opacity, not to mention the red impurity of the violet stain. But if the contrast red or yellow be also dark the screen may be required unless our plate be very much corrected for color.

It is not an uncommon occurence to find preparations very faintly stained with red, and it is still more common to find red stains and also yellow fade after a time. In such a case there is want of actinic contrast between object and ground, and the latter is exposed practically as fully as the former, and so we can not get a white ground in our positive. In such a case a rather dark yellow screen used either with an ordinary or an orthochromatic plate will prove of great service. Bacteriological preparations seem to be specially subject to this fading, and we have many times got good results with a yellow screen after repeated failures without one.

Insect preparations and others similar, where we have yellows approaching opacity at times are very difficult. Sometimes the best result is got by using an ordinary plate without any screen, sometimes a yellow-sensitive plate without screen, sometimes the latter plate with a screen added, sometimes a cobalt blue screen, and sometimes a signal green. The best procedure depends upon the depth and quality of the yellow in the object. The common flea as usually mounted seems to come out best with an ordinary plate, but we possess one which curiously enough requires not only a yellow-sensitive plate—which pro-

duces differentiation in the body-color of the insect—but a yellow screen which prevents the background from being over-exposed. It must always be remembered in dealing with orthochromatics that we cannot always make practice agree with theory, and the only way to succeed with some objects is to "ring the changes" till we do succeed.

Without color-correct photography it would be found well-nigh impossible to photograph any thin section or very minute object stained lightly with that very useful dye, gentian violet. The same remark applies to another favorite stain, methyl blue. Gentian violet used with an orthochromatic plate in presence of a yellow screen, or illuminated by an oil lamp, is, in our opinion, the most satisfactory stain for nearly all bacteria, for, in fact, all that are amenable to the violet stain. And methyl blue is a very useful contrast stain for such micro-organisms as we choose to stain red. If a preparation be stained with a clear violet so as to show body-details in the object, or if a preparation is double stained, red and blue, then a color-correct plate, generally helped by yellow screen or yellow light, will give renderings quite beyond the reach of an ordinary plate. This we have verified a hundred times.

"Test" diatoms are sometimes mounted in media having very high refraction indices but of very yellow color. We refer to certain arsenic compounds used for the mounting of *Amphipleura pellucida* and such like. Over and above a difficulty entailed by the optical principles involved when we are working at very wide numerical apertures, this yellowness of the mounting medium makes it very difficult to get a white background in our print. A yellow-sensitive plate used without a screen frequently lessens the difficulty alluded to in connection with the background.

In concluding this chapter we can only say that while we apologize for the meagre amount of definite instruction given by us under this head, it must be remembered that the varieties of color and shade are almost infinite; that unfortunately language is not sufficiently accurate to permit of accurate color nomenclature; and lastly, that experience alone can teach us how best to choose a suitable plate and a suitable screen for each subject as it falls to our lot to photograph it.

Our latest color sensitizing bath is due to Mr. Bothamley, and gives considerable sensitiveness to yellow, but not to red. The *general* sensitiveness of the plate is raised about three times, and the aptitude for giving density greatly increased. No washing is required, and the plates keep well. A rather slow plate should be chosen, and the caution about proportion of iodide must be kept in mind. The proper erythrosin is that of the *Badische-anilin-and-soda-fabrik*, called "Erythrosin B." The use of ammonia in this way is covered by patent in England. The ammonia may be omitted, but five or six times more exposure will be required. (Bothamley.)

Erythrosin solution (1 to 1000)	1 part.
Ammonia (1 to 10)	1 part.
Distilled water	8 parts.

Bathe the plate for two minutes. Dry. No washing needed.

PART II.—PRINTING PROCESSES.

INTRODUCTORY.

It is hardly within our scope, and it is certainly not our intention, to enter here at any great length into printing processes. After a negative has been obtained the process of producing a print or prints is purely photographic, and full instructions for printing by the many processes available are to be found in many purely photographic books; for example, the reader will find ample instruction on the subject in the book already repeatedly alluded to: "The Processes of Pure Photography," by Professor Burton and the present writer, forming one of the series of publications of which the present book forms another item.

Still by attention to certain details in the ordinary photographic processes points prëeminently important to the photo-micrographer may be emphasized, and our present instructions shall tend to work chiefly upon points affecting specially the printing of a photo-micrographic negative.

The processes we propose to treat thus briefly are:

The albumen paper silver process	Paper prints by contact.
The gelatine chloride emulsion process	
The gelatine bromide emulsion process	
The platinotype process	

Enlarging on bromide paper.
Lantern slides by contact and by reduction.

CHAPTER XVII.

PRINTING ON ALBUMENIZED PAPER.

This process is the one most commonly used by photographers for producing their prints in the ordinary course of work; for our purpose it is well adapted, as it lends itself to the rendering of fine details in a fairly satisfactory manner; the image is not lost and made granular by being deposited in the texture of the paper as in some other processes; but the very finest details either in shadows or in high lights are apt to be lost in the operations of "toning" and "fixing," however carefully these operations may be performed. Shadow details are greatly emphasized and generally improved by the process of enamelling, to which we shall call attention at the end of this chapter.

Paper of special quality is coated by special machinery with albumen containing a certain amount of chloride, usually ammonic or sodic. This is floated upon a solution of argentic nitrate and by double decomposition argentic chloride is formed and remains in the albumen layer with a certain necessary excess of argentic nitrate. Argentic chloride in such conditions darkens under the action of white light; the black parts of a negative prevent access of light to the parts of the sensitive paper in contact with the negative, the light parts of the negative allow the light to pass and affect the paper, and so a "print" is obtained. The print thus obtained if not "fixed" would soon turn black all over, so it must be fixed in sodic hypo-sulphite, but this would leave the print with a very unpleasant color, so before fixing we "tone" the print by causing a layer of gold to be deposited over the image; this gold, being deposited over the peculiar gradations of color proper to the reduced chloride and albuminate of silver, gives various color or "tones" according to the color of the sub-

jacent image and the fineness of division of the gold itself. The fixing operation does not remove the tone produced by the gold; and, moreover, the gold imparts to the image an ability to withstand atmospheric and other actions which but for the gold would soon destroy the beauty of the image.

The paper is almost always bought ready albumenized and "salted," and very frequently ready sensitized also; in the latter case special processes are resorted to in order to make the paper keep good for a period of weeks or even months. We prefer the ready sensitized paper for general work, and in Britain it is easily obtained at very reasonable prices.

If, however, sensitized paper cannot be obtained, the albumenized salted paper is to be floated albumen downwards in a bath of argentic nitrate. (See page 64.) Time of floating 3 to 5 minutes according to temperature and nature of the albumenized paper. The higher the temperature the shorter should be the flotation.

The "bath" formulated on page 64 should be neutral or slightly alkaline, and must be kept up to strength, for of course each sheet of paper floated on it removes a certain quantity of silver.

When the negatives are "thin," full of detail but lacking contrast, the 60-grain bath—or a strong bath—should be used and full time of flotation given. "Hard" negatives may be printed on lightly sensitized paper, that is to say on paper floated on a weak bath, and only long enough to ensure complete conversion of the salt in the paper into silver salt. The ready sensitized papers usually give more brilliant prints, or more contrast, than paper sensitized at home and used immediately without "preservatives."

A hard negative is best printed in direct sunlight; a very thin negative should be printed in weak light, or in brighter light behind a sheet of ground-glass.

When flotation is finished, the sheet of paper is to be hung up in a cool dry place to dry; nothing must touch the face while it is damp, and the corners should not be allowed to curl inwards and so spoil the centre of the sheet. It is well to blot off each sheet as it leaves the sensitizing bath, having allowed

the sheet to drip as much as it will. Pure bibulous paper must be used for this purpose. If the sheet after drying is placed between sheets of blotting or pure filter paper previously impregnated with sodic carbonate and dried, it will remain white and good for weeks. Sensitizing and drying must be performed in yellow or artificial light. All these matters are most carefully treated in "Practical Guide to Photographic and Photo-mechanical Printing Process" by W. K. Burton, C. E. (London, Marion and Co.) and also in the book already alluded to in the Scovill Photographic Series.

The negative is laid face upwards in a "printing frame" (fig. 30.) and on it is laid the albumenized paper face downwards,

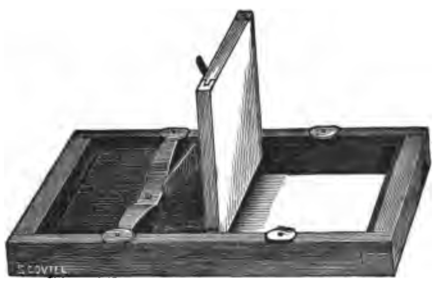


FIG. 30.—PRINTING FRAME.

so that the albumen surface is in contact with the gelatine film. The frame is then taken to the daylight and printing commences. As a rule photo-micrographic negatives, if thoroughly good, take longer to print than ordinary photographic negatives. In any case the printing must be carried considerably beyond the stage when the print seems to look at its best, as seen by opening one-half of the hinged back of the printing frame. The operations of toning and fixing greatly lessen the depth attained by the merely exposed print.

When a batch of prints are printed, having after printing been stored away in some suitable light-tight receptacle, we proceed to the operations of toning, fixing, and washing.

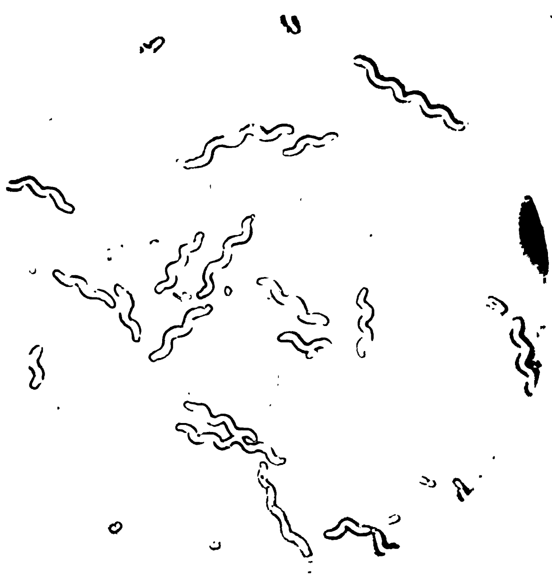
The prints are first immersed in water, being well covered therein and kept moving and separate from each other. After

about ten minutes they are moved into a fresh supply of water. If the paper is "ready sensitized" this second water should contain a small dose of sodic carbonate sufficient to neutralize the acidity of such paper. If the paper is home-made, and if it is not brick red on entering the second water, a pinch of common salt (sodic chloride) must be added to the second water. The prints must go into the toning-bath red, not violet or purple. As a rule the print should pass through four changes of water before being toned.

The toning-bath preferred by us, the only one we think it necessary here to give will be found on page 64. It is to be poured into a white perfectly clean flat dish large enough to hold two prints side by side, and deep enough to allow one print to slip easily under another. The temperature of the toning-bath should be about 65 deg. Fahr., not under 60 deg. nor over 70 deg. The prints are put in face downwards and *kept moving*. The Toning Solution *must* be alkaline; an acid toning solution is the commonest of all amateurs' printing troubles. The prints ought in from ten to twenty minutes to change from brick red to a handsome color, brown, purple, or warm blue-black according to taste and time. (Prints always turn a little more blue after drying.) Home sensitized paper usually tones more quickly than ready sensitized. It is an advantage to get as much gold as possible deposited without turning the prints blue; that amounts to our saying that it is better to tone slowly than quickly. If the bath is too strong in gold the prints turn blue very quickly, but the blue is only superficial and comes away in the fixing bath leaving the print practically untoned. A fairly good rule is to stop the toning when the print has, seen by reflected light, a good color inclined to be warmer than we desire our finished print, seen by transmitted light just a suspicion of blueness in the half tones of the higher lights.

After toning, the prints are put into clean cold water and there kept moving if possible. A trace, however slight, of hypo in the toning solution ruins it, the greatest care is therefore to be exercised to keep these solutions apart. The toning bath should seldom be filtered, but gold chloride must be added

No. 1.—B. Anthracis in Blood. × 750.



No. 2.—Spermatozoa of Triton, × 1000.

PLATE IV.

to replace the quantity taken out by the prints, and each time gold is added the bath should be tested for acidity and alkalized slightly if necessary. The gold salt is usually sold in sealed tubes containing fifteen grains; one of these tubes may be scratched with a file, put into a two-ounce bottle, the tube broken and water added to fill the bottle. One dram of this contains about one grain of gold chloride, and a sheet of paper (17x22 inches) may be expected to take up about one grain of gold salt.

From the fresh water after toning the prints are to be put into a fixing bath of sodic hyposulphite, made decidedly alkaline, as on page 64. In this they are to be kept separate, in motion, and for a period ranging from 12 to 18 minutes. A very light print may be removed in case of need after 8 or 10 minutes. The prints, if on "double albumenized" paper—a quality having a high gloss—are to be put direct from the hypo bath into water containing, to each pint, about an ounce of common salt; this is to prevent blisters, which are apt to occur. Then the prints must be very thoroughly washed, an easy matter if the proper means be taken, a very difficult one if commercial washing machines are the only apparatus used. Our plan is to lay each print down on a slab of glass or vulcanite under a rose tap, and to pass a squeegee many times briskly over the back of the print, occasionally turning the print face upwards to get some water, but not any squeegeeing, of course.

After a few changes of water and applications such as this, one of the washing machines may be trusted to finish the elimination of the hypo, in four to six hours; the water running constantly and being syphoned off *from the bottom* of the washing trough. After thorough washing, the prints may be dried or blotted off, but before they are quite dry they should be rolled one by one, *face outwards*, round a ruler or other roller of hard wood, and there left till they are dry, or till they retain the outward curl.

The effect of glazing or enamelling the face of a print is to produce an appearance not, perhaps, artistic, but in some cases, such as ours, desirable. The shadow details are greatly assisted by this gloss. The simplest way we know to impart a gloss to the albumen print is to place the print, washed but still wet,

with its face in contact with a sheet of "ferrotype plate" having a highly glazed impervious surface. If the ferrotype plate is clean the print, as it dries, will leave the plate either spontaneously or with very slight assistance. A plate of glass rubbed with pure talc powdered (French chalk) may be used instead of the ferrotype plate. A still higher glaze may be obtained thus: Make a solution of good gelatine ½ to 1 ounce, water 10 ounces. Swell the gelatine in the water, then dissolve by heat. Take a sheet of glass, free from scratches, clean well, sprinkle over with powdered talc from a pepper box or muslin bag. Rub the talc all over; then all (apparently) off. Coat the plate with plain collodion. When the collodion is set, but not dry, wash it under a tap or in changes of water till the greasy appearance is gone. Place the collodionised plate face upwards in a flat, clean dish, containing the melted gelatine, submerge the print to be enamelled face upwards in the gelatine, bring plate and print up together face to face; put a sheet of waterproof cloth over the print and carefully squeegee the print to the collodion surface of the glass plate, avoiding air bells. Allow to dry, run a knife edge round the edges of the print, when it will probably jump from the glass with a very highly glazed surface. The drier the print at time of stripping the higher will be the gloss. It is not absolutely necessary to immerse the plate in the gelatine solution; if the print is thoroughly saturated with the solution, it may be laid down on the collodionised glass and then squeegeed.

If these enamelled prints are to be mounted on cards, it is well to pass a card of no great thickness through hot water and to place it behind the print on the glass, while the print is still saturated with gelatine, and then to squeegee all together, placing a flat board on back of the card after squeegeeing and leaving a weight on the board for a considerable time, to prevent the card from bending away from the print.

If the reader propose to mount his own prints of every description, he will probably find fresh starch paste as convenient and as efficient as any mountant. Pour a little cold water on the starch, make a thick cream with it, then add hot water. Flour paste must never be used. Gelatine dissolved in water and spirits is with some a favorite mountant.

CHAPTER XVIII.

GELATINE CHLORIDE PAPER.

By some manufacturers paper is coated with emulsion of gelatine chloride (argentic) with a certain excess of argentic organic salt, and paper so prepared is used for "printing-out" in a manner very similar to albumen paper. (The term "printing-out" is used to signify a process wherein the image is revealed by the action of light alone, in contradistinction to the term "printing by development," where after light-action the image is wholly invisible or only faint, and development is required to bring the image to its full vigor.)

The practice of printing the gelatine-chloride paper is precisely similar to the practice with albumen paper. A few details of difference may be noted as to the properties of the papers. The gelatine-chloride paper gives much more contrast than ordinary albumenized paper, so where we have thin weak negatives the former offers a great advantage. The gelatine paper seems, as a rule, to lose as much depth in operations following printing, but seems to require a considerably larger quantity of gold chloride to produce the toning effect. The printing of the gelatine paper is usually more rapid than that of the albumen paper.

After printing with Dr. Liesegang's paper no washing is required, but the prints are at once toned in a bath made thus:

Water	24 ounces
Sodic hyposulphite	6 ounces
Ammonic sulpho-cyanide	1 ounce
Saturated aqueous solution of potash alum	2 ounces

Dissolve, and place in the solution some scraps of gelatine-chloride paper for about 24 hours. Filter, then add:

Water	6 ounces
Auric terchloride	15 grains
Ammonic chloride	30 grains

This bath tones and fixes at one operation. To judge of the color we must look through the print, reflected light will mislead us. It is not easy to overtone by this process.

Obernetter's Aristotype paper has in our hands worked best with separate toning and fixing baths.

TONING SOLUTION.

Ammonic sulpho-cyanide	140 grains
Sodic phosphate	140 grains
Sodic tungstate	100 grains
Water	24 ounces

Dissolve. Put in scraps of paper as above, filter, then add:

Auric terchloride	15 grains
Water	4 ounces

Tone to a rich brown color—or into blue if desired—then, after washing, fix in weak hypo; viz.:

Hypo	1 part
Water	10 parts

These papers may be dried with their natural surface or may be highly glazed by squeegeeing to ferrotype, vulcanite, talced glass, or collodionized talced glass, as described in last chapter.

CHAPTER XIX.

PRINTING ON BROMIDE PAPER.

This printing process is on the whole, perhaps, the most satisfactory and convenient of all for the photo-micrographer. The author always produces by this process prints intended for special purposes of exhibition, which is a fair guarantee of his own opinion, at least.

The photo-micrographer whose time is, perhaps, pretty fully occupied with other business will find the bromide paper process convenient from its celerity, and satisfactory on account of the beauty of the results that by a little practice may be obtained. There are certainly difficulties in the process, but as they will all be overcome by care and practice, they need not appal us.

The process is one of exposure—to artificial light as a rule—and development, by ferrous oxalate generally. There is no protracted period of printing, no watching of the progress of printing, no toning nor serious washing before fixing.

To attain speedily to success, and to ensure repetition of success with the same or similar negatives, the worker should in the first place obtain a standard light. A "regulator gas-burner" or an oil lamp always turned to the same height, or a standard candle, or a fixed length of magnesium ribbon, or wire, or a "unit lamp," any of these is suitable. We may also fix either a standard distance from the radiant, varying our exposure, or we may fix upon a standard exposure, and vary our distance from the radiant. Our own preference is to have a normal distance from light to sensitive surface of, say, 18 inches, and to vary the exposure according to our negative, and this practice we recommend to beginners, though the more experienced will find a marked advantage, without introducing insuperable difficulties, in varying both distance and exposure

to meet certain peculiarities of negative. In varying the distances, however, we must not overlook the law regarding the intensity of light, viz: that the intensity varies inversely as the *squares* of the distances between radiant and recipient; in other words that halving the distance is equivalent to quadrupling the exposure. If the correct exposure at 18 inches be twenty seconds, at 30 about 55 seconds will be required, as $18^2 : 30^2 :: 20 : 55\frac{5}{9}$.

If magnesium ribbon be used it will be found convenient to burn each time a definite length, say one inch, and to vary the distance of the printing frame from the burning wire. A number of prints may be exposed at one operation with magnesium wire by arranging the frames in a circle, or at various parts of several circles, either imaginary or actually traced on the table.

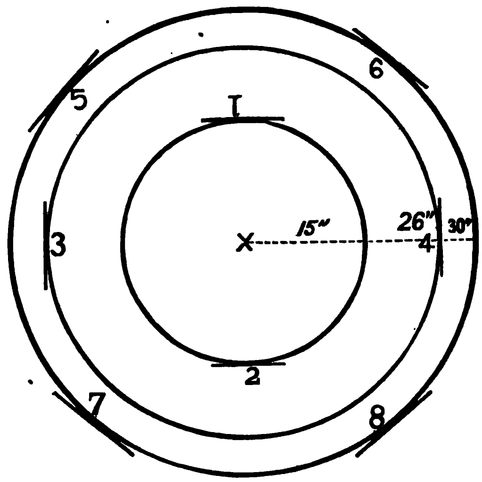


FIG. 31.

By such an arrangement as shown at figure 31 we may evidently expose with one length of wire or ribbon, burned at "X," eight negatives of three grades of density at one time.

"Bromide paper," as it is usually called by photographers, is a good quality of paper coated with an emulsion of gelatine-bromide of silver, a considerable proportion of chloride

being sometimes added. The sensitiveness of the emulsion varies in different makers' products, but it is usually considerably higher than any collodion emulsion, and always lower by a good deal than that of such gelatine bromide plates as are used for the production of negatives. In order that the paper may not curl and become unmanageable in aqueous solutions, the gelatine film ought to be very thin; and to counterbalance its thinness it ought to contain a high proportion of the argentic salts, otherwise vigor of image will be difficult to attain.

The paper is placed face to face with a negative in a frame in the usual way for contact printing, but this operation must be performed in non-actinic light, a simple yellow glass not being sufficient protection against daylight, nor even against ordinary artificial light. If there is any doubt as to which is the face—or gelatine side—of the paper, it may be laid down for a few moments on a flat surface, and it will soon show signs of curling *face inwards*. Makers usually send out three qualities of bromide paper: A—Thin paper with a surface glossy; B—Thicker paper with surface glossy; C—Thick paper with a mat surface, which is not recommended for our purpose. The sensitiveness does not appear to be affected in any way by the surface, all grades being practically alike sensitive.

The development is usually effected by ferrous oxalate, the constituents being used in the proportions of from 4 to 6 parts of the potassic oxalate to 1 part of the ferrous sulphate (see page 63). We recommend the addition of at least one-half a grain of soluble bromide to each ounce of developer.

We have assumed a standard light and a standard distance from light to printing frame. We now remark regarding exposure:

A dense negative requires long exposure, and *vice versa*.

Long exposure tends to softness, detail, want of contrast.

Short exposure tends to brilliance, contrast, pluck.

Over-prolonged exposure leads, as a rule, to an unpleasant color; a greenish tint, which is undesirable.

Too short exposure leads to "chalk and soot," dense black shadows, and glaring whites.

A strong developer (say 4 oxalate to 1 iron) gives good brisk blacks, a weak developer (say 1 to 7) is apt to yield "washed out" tones of the image, while a *very* weak developer sometimes produces a peculiar appearance of measliness or grain.

If we have to print a weak, "ghostly" negative, we keep down the exposure and develop with a brisk developer restrained with a full dose of free bromide, say 1 grain bromide per ounce of developer. If our negative is hard or shows violent contrast, we give a prolonged exposure and use a developer consisting of, perhaps, 1 part of iron to 6 of potassic oxalate, and even to this some water may be added, while the free bromide may be reduced, or even omitted.

One strong point, perhaps the strongest point in favor of this process is that it lends itself above all other printing processes to the production of good prints from inferior negatives, and enables us to vary to a very marked extent the prints we may obtain from any one negative. A negative showing little more than a ghost of an image may be made to yield a print actually "hard;" while a negative of the "chalk and soot" order may be made to yield a print of the utmost softness, and these effects may be produced by a mere variation of the exposure, assisted or unassisted by intelligent variation of development.

The manipulation of bromide paper is simple. After the exposure the sheet of paper is plunged into clean water in such a manner as to prevent formation of air bells; if bubbles do occur they are easily seen and must instantly be removed by hand or with a clean camel hair-brush. As soon as the paper lies flat in the dish it may be transferred face upwards to the developing dish, or if the same dish is to be used for both operations of soaking and washing, the water only requires to be poured out of the first dish and the paper left in it face upwards. The ferrous oxalate developer is now poured over the paper. (See page 92.) The developer should be allowed to act until the shadows of the picture show a good pronounced black as seen by the subdued colored light of the operating room. By this time the highest lights should not show any

grayness, while the half-tones should be from pale to dark gray according to their nature. In *our* work there ought always to be some part of the picture perfectly white when development is complete, but often it is impossible to attain this; our best guide then, remains in the vigorous tone of the dark parts. With the developer we have given on page 92 the image ought not to begin to appear for at least 20 seconds, and development with fresh solution may be expected to finish in about two to three minutes. Very rapid development points to overexposure, which is probably the most serious error that in our special work can be committed.

As soon as development is complete, the print is to be flooded with acidulated water, *not plain water*. A dram of acetic acid (glacial) to one pint of water will do, or a dram of citric acid. If the water smells of acetic acid it will suffice. Three applications of acid water for a minute or so each will suffice to wash out most of the iron, the print being moved in the acid water all the time; washing in plain water till the acid is eliminated follows, and then the print is fixed in the ordinary bath of hypo, 1 part, water 5 parts made alkaline. In this the prints should stay at least twenty minutes, then they are washed in the manner detailed for albumen prints. (Page 119.)

The Eastman Company of Rochester, U. S., prepare not only bromide papers of the very highest quality, but also a modification called Transferotype Paper. For the photomicrographer "Transferotype" is a most valuable process. The printing and other processes, up to and including the final washing, are exactly the same as for ordinary bromide paper, but as in transferotype the sensitive emulsion (insoluble) is laid over a soluble stratum of gelatine on the paper, it is evident that by dissolving the soluble gelatine we can remove the paper. If we can stick our image-bearing film to a transparent, or semi-transparent, or translucent support, as glass or opal, and then remove the paper, it is evident that we can produce a transparent or translucent positive—reversed as regards right and left certainly, but for us this reversal is of no import.

By the following means, then, we can produce by "Trans-

fer" a lantern-slide, transparent positive, or "opal print." After the final washing, which in the present case need not be so very laborious as if no further ablution were to take place, we place our transferotype print face to face with a perfectly clean sheet of glass or opal, squeegee the two together, place a double layer of blotting paper over the print, then a flat piece of wood, then on the wood a slight weight, as one pound. After about half an hour we place the support bearing the print in water at about 100 deg. Fahr. or higher, and soon the paper will float, or may be carefully lifted off. The film is then washed under the tap, getting a gentle rubbing with the soft pads of the fingers if necessary to remove any gelatine adhering to the picture; acidified alum may follow this washing. (See formula on page 63.) After the cleaning with alum the plate is finally washed, dried and varnished with a clear varnish usually called "crystal varnish."

Bromide papers "A" and "B" may have a greater or smaller amount of glaze conferred on them by one of the following methods. A fairly glazed surface may be obtained by squeegeeing the finished and washed prints to a sheet of vulcanite. When dry they will come, or may be taken from the vulcanite, and will have a very good glossy surface. Talced glass may be used in place of the vulcanite. Or glass talced and collodionized as on page 120 may be used, and this will not only give a very high gloss but will tend to protect the surface from scratches and from damp.

Transferotype prints may be dried naturally and the paper removed at any future time. Previous, in such a case, to squeegeeing to the rigid support, the prints must be very thoroughly wetted in water, and they must not have undergone alum treatment. Bromide prints and transferotype prints may be developed with pyro, and by some workers the pyro-developer is used with a view to warmer tones. The hydroquinone developer as formulated on a later page (page 152) answers most admirably for bromide prints and also, of course, for transferotypes; for bromide prints on "A," "B," or "C" paper we consider the hydroquinone developer superior in certain respects to all other developers; the regularity of

development, the scope allowed for variations in exposure, provided the exposure has been *sufficient*, and the color of the deposit or image, lead us to recommend this developer with much confidence. But the pyro and hydroquinone developers so act upon the soluble substance of transferotype paper as to make the stripping—not by any means impossible nor even difficult—but less easy than after ferrous oxalate development.

The image on bromide or transferotype paper can by various proceedings after fixation be toned to various colors; for details of these matters we must refer our reader to general photographic literature.

The method of developing bromide papers for enlargements and transferotype paper for lantern slides is practically identical with the method we have given in this chapter.

Bromide paper offers a vastly greater prospect of permanence of result than other silver printing processes; in fact a bromide paper print produced with proper precautions is in point of permanence, as it is in point of beauty, inferior to no purely photographic print that at present we know how to produce.

A very pretty effect may be produced by attaching a number of transferotype prints, arranged in an artistic manner, to a sheet of opal. The prints being trimmed with scissors to the desired shapes are, in the bath of plain water after fixing and washing, caused to adhere to the opal plate in their desired positions. The plate bearing the prints is in the usual way removed from the water and the prints are carefully squeegeed into perfect contact. The prints are then *allowed to dry*, and the stripping in hot water performed thereafter.

CHAPTER XX.

THE PLATINOTYPE PROCESS.

THIS is a process due mainly to the ingenuity and chemical skill of Mr. W. Willis, of London, England, and is so far protected by patent laws that in this country the original platinotype process can only be worked under license from the company,* and with, for the most part, materials provided by the company. The process has a strong claim on our attention on account of its almost indubitable permanence, the image consisting of metallic platinum, and on account of the great beauty of its results under favorable conditions. On these two accounts we think it right to give at least a brief description of the process; but except for special micrographic purposes—and these practically of one class—we do not put forward this process as eminently suited to the photo-micrographer. Where extreme fineness and definition of detail is a necessity no printing process by which the image is deposited in the substance of a textile such as paper, can be expected to compete with a process whereby the image is kept on the surface and prevented from "losing itself" among the fibres of the textile by a surface-medium such as albumen or gelatine. But where fineness of detail and sharpness of outline are secondary, and indubitable permanence paramount considerations, this platinotype process is to be strongly recommended when the negatives are of high technical quality. But unless the negatives are tolerably good in a technical sense, *i.e.* unless they show a considerable range of gradation from high light to shadow, and unless they possess a reasonable amount of "pluck" or contrast, their rendering as printed in platinotype will not be satisfactory nor even tolerable.

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* We understand that this license is now unnecessary.

The image in platinotype printing becomes under the action of light visible; with the Platinotype Company's original process of image becomes rather faintly visible, with a new process lately introduced from Germany, the image "prints right out." With the latter process, known as Pizzighelli's, all that is required is to print the image to the required depth and then to "clear" it with a weak dilution of hydrochloric acid. The Company's ordinary paper is partly printed and partly developed.

For the Hot-bath Development process: The paper is obtained from the company ready sensitized, it must be kept away from light and *perfectly dry*. In order that it may be kept quite dry it should be placed in a calcium tube, a light-and-air-tight tube, having at one end a receptacle containing calcic chloride in some shape. Sometimes the paper is bought separately and the materials for sensitizing separately; in such cases full instructions accompany the goods. By means of varying the proportions of certain ingredients of the sensitizer, we may vary our results within limits or prepare a paper more suitable than the ordinary commercial article to our negatives.

Every precaution must be taken with this paper to prevent it getting damp in the least degree. A sheet of India-rubber is put behind the paper and preferably overlapping it in the printing frame. Printing is carried on till the shadows take a very peculiar dirty green brown color, or until all the details are faintly visible over the print, except, in a few cases, in the very highest lights. After printing, the paper must again be stored with every precaution against light and damp. Any veil produced by light in this process is not, as in the albumen process, removed by the after operations of toning and fixing, for in platinotype there is no analogous "clearing" action. Therefore the progress of printing must be examined in the frame as rapidly as possible, and it may be noted that the process of printing is much more rapid with platinotype than with ordinary albumen paper.

To develop platinotype prints. Make a saturated aqueous solution of potassic oxalate at 60 degrees Fahr., and heat to

about 160 degrees in an enamelled flat iron dish, a Bunsen or other burner serving to keep the temperature up while a succession of prints are developed. On this hot solution made alkaline the print is laid for a few seconds; the previously pale image will almost instantly flash into a black picture, the high lights remaining for the time yellow. If the printing or exposure has been too short the developing solution should be hotter, say 180 degs., if the exposure was too long the bath should be more cool, say 110 degs. It will generally be found best to expose to such an extent that the development will be correct at 160 degs. We usually have slightly acidified the bath with oxalic acid and got fine results, but the Company now recommend that the bath be kept faintly alkaline.

After development, which, conducted as above, will not occupy more than 15 or 20 seconds even with a "cool" solution such as suggested, the print is to be put straight into:

Water,..	60 parts.
Hydrochloric Acid,..............................	1 "

Two more baths of the same ingredients are to follow, and the third bath must never show any yellow tinge; if it does show such a tinge it must be followed by a fourth bath. When No. 1 bath becomes very yellow it should be rejected and the others be advanced each a step, No. 2 becoming No. 1, etc. After the baths the prints are to be washed for about 15 minutes in running water to remove the acid; they are then finished.

Pizzighelli's paper requires no development, but at time of printing it must be slightly damp, *not wet*. To damp it we may breathe on it or put it into a box in company with pieces of wet blotting paper. Printing may be partly performed by light, and finished with cold solution:

Saturated Solution Sodic Carbonate,..............	5 parts.
Distilled Water,..................................	100 "

Clearing is performed as above.

The latest process put forward by the Platinotype Company is convenient and good. The company send out with the paper

not only a salt, the nature of which they do not state, but the platinum salt which is not in this case present in the paper at first. Full instructions are given with the paper, and these directions are so complete and accurate that failure is unlikely if the negatives be suitable for the process. The printing is performed in a frame and by daylight, as before, but after the printing, the paper is caused to take up a certain amount of moisture, which it readily does on exposure in a damp apartment or box, the damping and the printing being kept in certain relations to each other. Then follows development on the "cold bath," which gives the name to this process. Development is less rapid than with the hot bath; in fact, the print having been floated for a moment or two on the cold developing solution is usually thereafter held in the hands till development is seen to be complete. The clearing process in acid and the washing are as in the hot bath process.

CHAPTER XXI.

ENLARGING.

THIS is a somewhat important subject to the photo-micrographer, as it is frequently inconvenient to take at the first a negative as large as may ultimately be required. "Enlarging," as the word is technically used by photographers, will not, as some persons seem to think, help us to get any superior qualities to those which we can get by direct amplification properly managed, excepting only the one quality of size. If we have to produce a photograph of an uneven diatom *exempli gratiâ*, at a magnification of 300 diameters, we shall get it just as well, or better, by direct operation in the camera as by magnifying to 150 diameters in the camera, and then "enlarging" to 300 diameters, always provided that in our original direct operation we do not overtax our instruments. By "enlargement" we enlarge and accentuate the difference of focal planes in the original object just as much as we accentuate it by direct projection; and, what is more, we often introduce new aberrations in our system of "enlargement," unless we are tolerably *au fait* in our optics and careful in our operations.

In considering enlargement we have two optical systems to attend to. 1st. A system for collecting light and transmitting it through our original negative or positive, or for concentrating the light passing through our original at or near a certain point with reference to our projecting system. 2d. Our projecting system, which regulates the sizes of our enlarged image and projects it upon our sensitive surface.

Our condensing or transmitting system depends chiefly upon the sensitiveness of our photographic receiving surface; if the latter is very sensitive and our light reasonably actinic, we require no condenser at all. But if either our receiving surface

is little sensitive as albumen paper, or our radiant little actinic as an oil lamp, then in practice we require an optical system known as a condenser.

As we propose to treat of two methods only of enlarging we shall touch but lightly on the subject of condensers. Our purpose is to confine ourselves to the use of such sensitive materials as gelatine-bromide emulsion, in which case we use daylight reflected or diffused, and transmitted in parallel pencils through the original; or failing daylight, artificial light concentrated and transmitted in converging pencils through the original to a certain point at or near the optical centre of the projecting system.

Enlarging by Daylight.

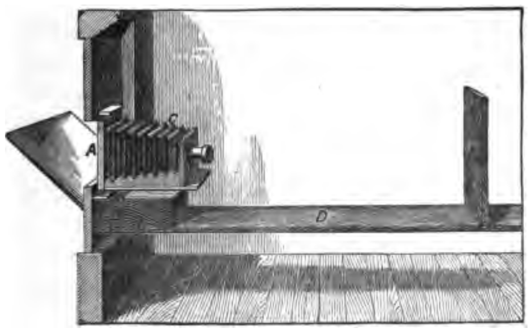
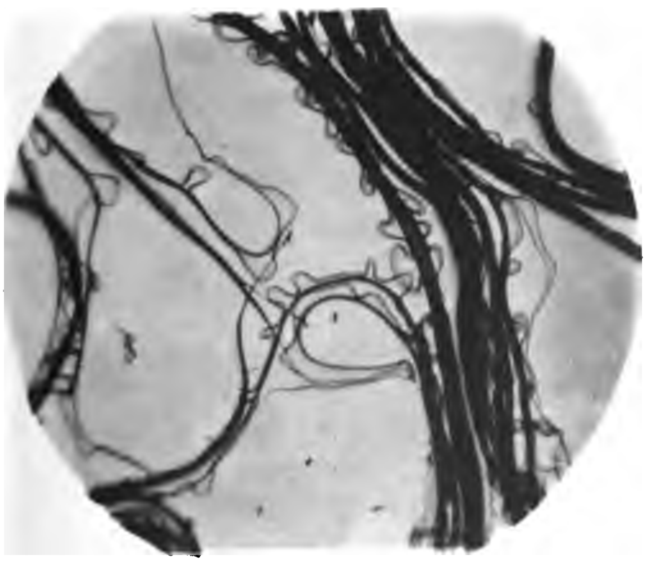


Fig. 32.

The cut (Fig. 32) shows almost at a glance an arrangement which if carried out in a reasonably workmanlike manner, will fulfil every desideratum for enlargement by ordinary diffused daylight. C is a camera capable of holding in its dark slide the negative from which we propose to make an enlarged print on paper or glass. C is fixed in any convenient manner to the sides of an aperture, A, in a wall or shutter preferably facing the north. F is a reflector of white blotting paper or any mat white surface, not a mirror nor any shiny surface; E is an easel sliding easily along the base-board D; E must keep at all times parallel to the negative in the camera, and to start with

No. 1.—" Pneumococci," encapsuled, × 500.



No. 2.—Flagellated Spirilla (? Serpens). × 800.

PLATE V.

stopping down of the projection lens which will entail greatly prolonged exposure. The usual "motions" of the large camera "rise and fall" and "traverse" of the front, will enable us to arrange our image on the ground-glass; while the small camera carrying the negative will by its rack and pinion enable us to arrange the magnification. The focusing of course is done on the ground-glass, and with the rack and pinion of the large

FIG. 33.

camera. The small camera's back is pointed towards the light, and an angled reflector, or ground-glass "diffuser" is used as before. With this arrangement there may be a difficulty in focusing due to want of light; in this case plain glass may be substituted for ground-glass, and the focusing done with an eye-piece of the Ramsden, or "Zeiss Aplanat" type.

In enlarging, as in most photographic processes, the *crux* of the whole affair is the exposure, and it is just as hopeless here for us to attempt to give rules for all conditions as it is elsewhere. All we can say is that *cœteris paribus* exposure varies directly as diameters of enlargement. That is to say: with a given negative, given light, given lens, given diaphragm, and given sensitive material, it will take twice as much exposure to enlarge a quarter plate to $8\frac{1}{2} \times 6\frac{1}{2}$ as it will take to enlarge it to $6\frac{1}{2} \times 4\frac{1}{4}$. The best way is to make a trial exposure—on a small piece of the paper and at the distance to be used seriously—and to develop it, noting carefully our remarks as to the appearance on development of under and over-exposed prints under the appropriate headings. With an arrangement, as shown in Fig. 32, and an average negative, using a 13-inch rectilinear at full aperture ($\frac{f}{8}$) and Eastman's bromide paper, the daylight being of average autumn quality, to enlarge three diameters the writer exposes from five to six minutes with ground glass diffuser, rather less with white reflector alone. But his average photo-micrographic negative is a dense one compared with a landscape negative, not to mention a portrait one. If the lens has to be stopped down to prevent spherical aberration, the exposure will be greatly increased, generally double for each next smaller size of stop as sent out by opticians.

A "table of enlargements" will be found in this book, and with it the worker may easily reckon approximately the position of lens and easel for any given operation. The camera bearing the lens may at any rate be racked to the desired extent, and then the focusing may be accurately performed by sliding the easel. The front motions of the camera may be used to arrange the image suitably on the screen. Focusing, if not done from behind with ground glass as suggested, may be done by viewing the projected image on a white sheet of paper afterwards to be replaced by the sensitive paper or glass, but in our experience the former method is vastly superior.

Enlarging by optical lantern: This is perhaps the favorite system among amateurs who are likely to possess an optical lantern for its ordinary use. Some of the laws touching the optics of this system must be noticed.

In the first place, an artificial light is used, and that light not remarkably powerful or actinic in comparison with daylight, and, moreover, the light is used in a lantern and not many inches distant from the original which is to be enlarged. So in the absence of a condenser we should have not only a weak but an uneven light, for the margins of our original would be much less strongly lighted than the centre. We here give a cut which will explain the functions of a condenser.

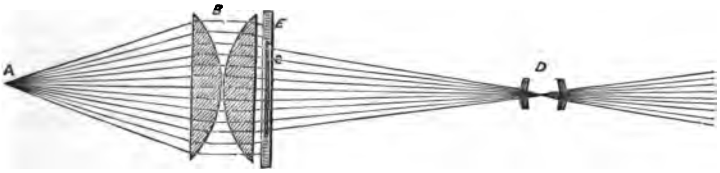


Fig. 34.

A is the radiant; *B*, a condenser of two elements; *C*, the original negative or positive held in frame *E*; the front focus of the condenser falls at a point inside a doublet lens *D*, the rays having passed through the original, except some marginal rays which might be used but are stopped by portions of the frame *E*.

Theoretically the radiant should be a point, and that point accurately in the focus of the condenser. Practically we cannot get such a point, the electric arc approaches most nearly to a point, the oxy-hydrogen mixing-jet lime-light next, a "blow-through" lime-jet perhaps next, and so on down to the worst of all—a multiple-wicked oil lamp. Still even the three-wicked lamp may in practice be successfully used, especially if we adopt an ingenious little contrivance due to Mr. Traill Taylor (Editor of the *British Journal of Photography*). Mr. Taylor's suggestion was a simple converging lens placed between the light and the condenser, the supplementary lens collecting rays that would otherwise not reach the condenser.

The area of the condenser must evidently be not less than, and ought to be greater than, the area of the portion of the original we propose to enlarge. The diameter of the condenser

must at least equal the diagonal of the plate or portion of plate we mean to enlarge. Thus the ordinary four-inch condenser of the optical lantern is not of sufficient size to enlarge an entire quarter-plate. Moreover, the larger the condenser the more light it will collect, so that the exposure required, *cæteris paribus*, varies inversely as the area of the condenser.

In practice the light is placed as nearly as possible in the focus of the condenser, the negative and the condenser remain fixed in relation to each other, the lens for projection is racked backwards and forwards till the image is seen sharp on a translucent or opaque surface placed to receive the image, this surface being parallel to the original undergoing enlargement. The easel may run on a track, or may be on castors, we figure a most convenient form of arrangement made by the Eastman Company.

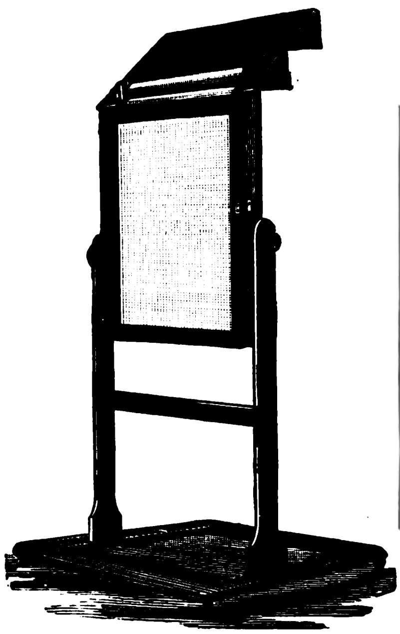


FIG. 35.

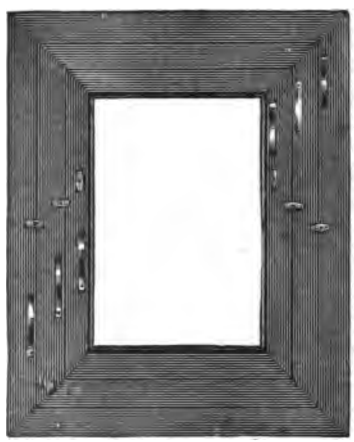


FIG. 35*a*.

This easel may very aptly be used for daylight enlarging by our first-described process.

The front of the lantern must be so arranged that the lens used for projection can be racked to at least twice its own focal length from the original.

In this process of enlarging (by the optical lantern) the relation between focal length of the projection lens and area of the original plays no part; a diaphragm is of little optical advantage, and to proper selection and use of our condenser we must look for success. We are as much incompetent here as in daylight enlargement to give rules for exposure, but the one rule we did give holds equally good here.

If by either daylight or lantern process we wish to produce an enlarged *negative*, two courses are open to us. 1st: We may make from our original (presumably a negative) an enlarged positive, and from that we may print "by contact" a negative. For this process we recommend a slow gelatine-bromide plate, such an emulsion as is made for lantern-slides answering admirably; or we may produce our large contact-negative by the carbon process, or on gelatine chloride emulsion. (For the carbon process consult "Processes of Pure Photography," or "Burton's Guide to Practical Printing," etc.) This is probably the better course if we enlarge by daylight. 2d: We may in the first place make a small positive by contact or reduction (according to the size of our original negative), and from this small positive we may make an enlarged negative on any suitable sensitive plate or film. A small positive such as would be a good lantern-slide is not so well adapted for this purpose as one almost fogged; that is to say, the positive for this purpose should be very fully exposed, more heavily developed than a lantern-slide, full of detail without absolutely clear glass; and presenting no violent contrasts.

Whatever be the sensitive material used to receive the enlargement, the after operations are the same as those given by us under the heads of development, etc., of the various sensitive materials treated in other chapters. Bromide paper and Transferotype, for instance, are treated just as if they had been exposed by contact, errors in exposure will manifest themselves in the same way in both cases.

If very sensitive emulsion is used, as for example an ordin-

ary negative gelatine plate, for making an enlarged negative, the greatest care must be taken to prevent extraneous light reaching the sensitive plate. If a lantern of the ordinary type is used it should be enclosed in a box, the lens only protruding through a fitting aperture.

In enlarging, beautiful effects may be produced very simply by judicious "vignetting"; an opaque mask having a suitably sized and shaped aperture cut in it may be moved towards and from the sensitive material during the exposure. Such matters are treated in most books devoted to photography.

CHAPTER XXII.

LANTERN SLIDES.

It is almost beyond question that the most useful, imposing and satisfactory method by which we can exhibit to others the result of our micrographic work, lies in the projection of a positive image upon a white, and proportionately large, surface called the "sheet" or "screen," by means of an Optical Lantern.

So strongly does the writer feel the importance of this subject that he proposes to devote a chapter to a plea for the use of the Lantern for many purposes. The present chapter will be devoted to a description of certain processes which seem to the writer most suitable for slide-making in the hands of those who are not thoroughly conversant with this branch of photography.

It is necessary in the first place to know precisely what qualities we require to obtain in a slide so that it may be a thoroughly good slide, or as nearly perfect as our subject and our negative will allow.

The first attribute to a slide, specially of a photo-micrographic slide, is perfect clearness of the ground. Wherever there is no subject the glass must be quite clear. A good slide laid down on a sheet of white paper, will show the paper, seen through the ground of the slide, perfectly white. There should in such condition be no graying or degradation of the purity of the white in the paper.

The image may be of various tones according to the process used, but it must always be "plucky," and never pale or "washed out," the details must stand out clearly from each other, as if etched with the finest needle. A perfect slide is indescribable but once seen will never be forgotten.

The image, though plucky, must not be opaque, except where the detail in the microscopic image was opaque. Such

an image as that of *amphipleura pellucida* should consist of pure white and absolute opacity, and the margins of black and white must be sharply cut. The microscopic image is really essentially an image of lines and points, but in many cases we have to show our lines so blended that the appearance is not one of lines but of masses resembling the masses of a portrait or landscape photograph. If we have such masses in a slide, they must be full of differentiation, or "half tone," as it may be called; anything approaching opacity here will be fatal. As instances of masses we may cite low power images of insects, physiological preparations, homogeneous tissues of any kind, "resolvable," perhaps, but not for our purpose "resolved." All such masses, then, must show half tone.

Essential, we have now seen, to a perfect slide are: *Clearness* of highest lights; *opacity* of resolved lines and points; *half tone* in masses; matter of taste is the *color* or tone; conventionally fixed is the *size;* and "*sharpness*" goes without saying.

It is necessary that the argentic deposit forming the image be very fine, partaking more of the nature of a stain than of a granular deposit. Makers of plates for slides are so well aware of this, and the processes for producing suitable emulsion for slides are so little prone to yield coarse deposits, that we need do no more than point out the *desideratum* of a fine grained image. But on this account, if on no other, gelatine bromide emulsion such as is used for negative production, is as a rule, totally unsuited for slide making purposes.

"Wet collodion" stands pre-eminent among processes for the production of photo-micrographic slides; on that point we have no doubt whatever. Perfect clearness of lights, complete opacity of lines when desired, sharpness, fineness of deposit, half tone in masses—all are obtained by the wet collodion process with a very reasonable exposure in the camera; for contact printing this process is not so convenient. But in any case camera copying is preferable to contact printing for our special purpose, even if our negative is the same size as our slide is to be. In landscape and portrait slides a warm tone is a very important feature, in the opinion of advanced photog-

raphers; in photo-micrography tone of slide is a very subordinate consideration, if, indeed, a black tone is not preferable.

Dry Collodion, which in virtue of its tone is perhaps the most suitable of all processes for landscape and portrait slides, gives purity of high lights little if at all inferior to wet collodion, but for camera copying the slowness of Dry Collodion is against it.

Gelatine-chloride plates are most valuable for contact printing, giving great clearness and varying tones at will, but for camera copying their excessive slowness is very unfavorable.

Gelatine bromide plates made for the purpose work rapidly and *may be made* to yield clear lights and good tones; but while assuredly the gelatine bromide process is the most convenient, and while its results under suitable conditions are inferior to none, still the greatest care and much practice are required in order that the working of the process may be mastered. Foggy slides by this process are unfortunately very common.

We have now put the merits of these processes fairly before our Reader. If he makes his negatives of a suitable size for contact printing we recommend on the whole the gelatine-chloride process, or dry collodion. (The latter process, however, we must not detail here for want of space.) But gelatine bromide may answer to perfection.

For camera copying we strongly recommend the wet collodion process, but as we fear few of our Readers will care to face its difficulties, or rather its inconveniences, we give as an alternative the gelatine bromide process.

The usual size of a Lantern Slide plate is 3¼ inches square, as a rule a mask is placed over this leaving an area of image of about 2¾ inches diameter.

To print by contact, the negative is placed face upwards in a printing frame, a Lantern Slide plate is placed face to face with the negative, the frame closed and the exposure made to the light in the usual position, *i. e.*, negative next the light. It is advisable that the extreme edges of the lantern plate be protected from the light by a mask or the rebates of the printing frame.

Reduction or copying in the camera may be performed most conveniently by the same arrangement as is figured No. 33 in our last chapter. The negative is placed in the "dark slide" of the large camera; distance is arranged by the rack and pinion of the large camera, centering by its front motions, while the lantern plate is held in the dark slide of the smaller camera with the rack of which, by aid of an eye-piece, focusing is performed in the usual way. The back of the large camera bearing the negative may be pointed at the sky, may be lighted by an angled mat white reflector, or may have a sheet of ground glass or tissue paper placed parallel with the negative and a few inches behind it. No light should get past the edges of the negative into the large camera, but this though a good precaution is not absolutely essential.

A still simpler mechanism consists in placing the negative against the pane of a window, lighting the negative either by a reflector or by the sky, and photographing it to the slide size in an ordinary camera. The day light enlarging apparatus figured 32 in last chapter may very easily be utilized for our present purpose, by simply fixing the negative in the window, turning the camera round, and suppressing the easel. The lens used must be rectilinear and may have a focus of 3½ inches or upwards. The author uses a "Rectilinear Stereo" lens of about 3½ inches focus.

The Wet Collodion Process for Slides.

In most books of photographic instructions that have any pretension to completeness, an account of the wet collodion process will be found. In "Processes of Pure Photography" the subject is treated with sufficient care to enable any one referring to that book to work out the process for himself, and to succeed with the process for our present purpose. We propose here merely to accentuate, as it were, certain directions given in the book alluded to.

Though a lantern-slide is only three and one-quarter inches square, it will be found almost necessary to use a larger plate with the wet process, and to cut it down after the slide is finished. Five inches by four will be a suitable size. The glass

must be very good, flat, polished, free from scratches, bubbles and other visible flaws. The glass must be cleaned, not only in the usual acceptation of the word, but made chemically clean by soaking for some hours in dilute acid (say nitric acid 1 part, water 10 parts). Thereafter it must be washed, preferably under a tap first, and then with a solution of sodic carbonate. Next it should be well rubbed with a clean cloth dipped in a mixture of alcohol and ammonia; lastly, it should be polished with a perfectly clean and soft chamois leather. For lantern slides we do *not* recommend any substratum of albumen.

The collodion may be bromo-iodised, as generally sold and used, but the iodide should be in strong proportion, the bromide being here of less consequence. The collodion should be rather limpid than thick, and should be moderately ripe, neither quite fresh nor very high-colored with age.

The "silver bath" may be the usual 35-grain one, and must be acid, preferably nitric acid being used. Of course this bath must have the usual trace of iodine, produced by immersion of a coated plate for some hours, or by the direct addition of an iodide. Either the flat or the dipping bath may be used, perhaps the latter is here preferable, as dust must be most zealously avoided. Operations of coating and sensitising are exactly as given in "Processes of Pure Photography," Chapter VI.

The developer may be the usual acid ferrous sulphate, or the ammonio-sulphate, or the pyrogallol. The latter developer requires the longest exposure, but gives magnificent results, especially if used with a collodion containing iodides only.

PYROGALLOL DEVELOPER.

Pyro	2 grains
Glacial acetic acid	30 minims
Water	1 ounce
Alcohol	q. s.

This solution should either be used fresh, or the pyro dissolved in alcohol in strong stock solution. The quantity of alcohol, which should be of good quality, depends on the age

of the silver bath, as the latter is more and more nearly saturated with the collodion solvents of the immersed plates, the more alcohol will be required. A fresh silver bath requires little or no alcohol in the developer.

FERROUS SULPHATE DEVELOPER.

Proto-sulphate of iron, fresh green crystals	15 grains
Nitric acid	1 minim
Water	1 ounce
Alcohol	q. s.

AMMONIO-SULPHATE DEVELOPER (FROM "PROCESSES").

Ammonio-sulphate of iron	77 grains
Acetic acid (glacial)	70 minims
Water	8 ounces
Alcohol	q. s.

One or other of these developing solutions is deftly swept over the plate from a cup, and no harm will be done with the iron developers if a little solution should run over the edge of the plate. The iron acts more rapidly than the pyro developer, and the latter should be carefully watched and instantly rejected if it shows signs of turbidity. In each case the solution is to be kept moving over the plate until the image has gained considerable strength, but none of the solutions is to be poured on and off the plate. As we do not approve of re-development for slide making, we advise that the developer be allowed to act fully, provided no muddiness appears. The plate is now washed, and fixed with

Potassic cyanide	20 grains
Water	1 ounce

Or,

Sodic hyposulphite	100 grains
Water	1 ounce

We prefer the cyanide, but it is a dangerous poison, the handiest antidote in case of accidental imbibition being a good draught of the iron developer. After fixing, the plate is to be well washed, particularly after hypo.

Frequently the slide at this stage wants "pluck." The remedy is intensification, but the remedy must be applied with caution.

Put into a clean cup about 10 drops of a solution of argentic nitrate, bath strength, acidified with nitric acid, add thereto about 4 drams of the pyro, or iron developer, pour this on the plate, but keep it moving, and beware of turbidity. Wash the plate.

The color may not be pleasing at this stage, in which case we resort to toning. Immerse the plate in

Platinic chloride	1 grain
Nitric acid	1 minim
Water	8 ounces

Watch the progress and remove the plate when the color is satisfactory. A fine color (engraving black) may be obtained by toning in this solution till the image is bleached and almost disappears, and then lightly intensifying with iron and silver as above.

Mr. Armstrong's Palladium Toning for Slides.

Palladic Chloride	15 grains
Water	15 ounces
Nitric acid	a trace

For each ounce of toner take 1 dram of this and 7 drams of water. Tone till the color penetrates right through the film, and is visible from back of the plate.

After the plate is dried and varnished with a clear varnish, (see page 60) it is cut down with a diamond to proper size.

Gelatine Chloride Plates for Slides.

Print in contact. As even with gas or oil light the exposure may be inconveniently long, a good plan is to burn a measured length (say 1 inch) of magnesium ribbon at certain distances, determined by trial, from the frame. For a beginning the inch of ribbon may be burned at 10 inches distance for a moderately dense negative. The exposure to diffused daylight may be from 5 seconds upwards. If magnesium be used a spirit-lamp may be utilized to ignite the ribbon, a spirit-lamp would require a very long time to impress the plate.

Devolopment is performed in a flat dish, the plate being placed therein face upwards, and the developer poured over the plate.

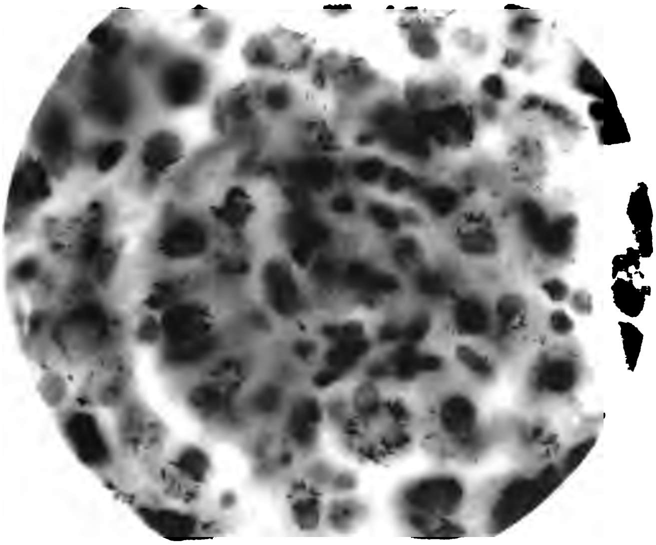
[illegible]

[illegible] ounces
[illegible]

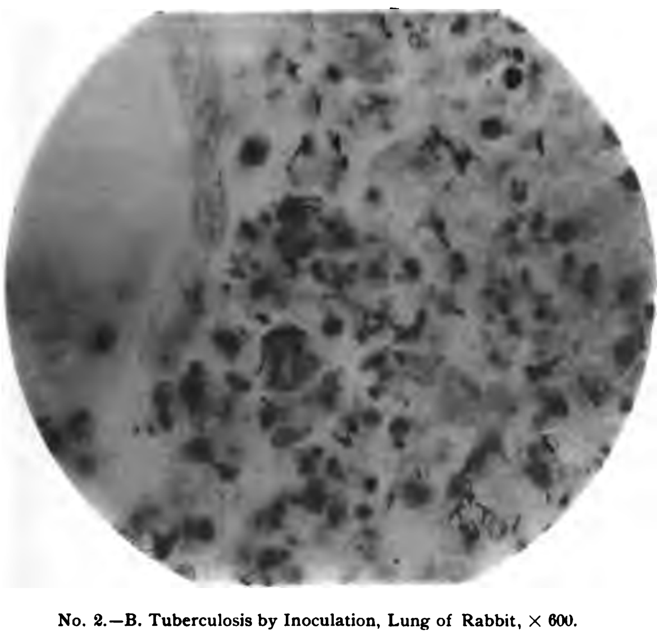
[illegible] Mr. Edwards [illegible]

[illegible]	8 ounces,	
[illegible]	20	"
[illegible]	80 grains	
[illegible]	8 ounces	
[illegible] carbonate	2	"
[illegible] bromide	40 grains	

[illegible] keep good for very long, but if the [illegible] in two parts and the carbonates separate [illegible]



No. 1.—Bacilli Tuberculosis in Lung of Horse, × 750.



No. 2.—B. Tuberculosis by Inoculation, Lung of Rabbit, × 600.

PLATE VI.

from the hydroquinone, the two solutions will keep for a long time, and may be mixed at time of need.

This developer acts very steadily; if exposure has been sufficient failure can hardly occur with suitable negatives and good plates, for the developing action only requires to be watched and stopped at the proper time. Fixing, washing, and clearing may be conducted as usual. This developer is strongly recommended for Bromide prints.

Alkaline Pyro Developer.

This is not recommended for our purpose unless there be some special desire for warm tones. Sodic Sulphite as a pyro preservative is to be avoided and preference given to potassic meta-bisulphite see page 61. An ounce of developer may be made to contain:

Pyro	1 to 1½ grain.
Potâssic Meta-bisulphite.	2 to 3 grains.
Liquor Ammonia. 880	2 minims.
Potassic or Ammonic Bromide...	2 grains.
Water	to 1 ounce.

The *rationale* of developers, of which the above may be called illustrative, is simply a well restrained development, the potassic salt tending to produce a warm tone, coupled with full exposure and "willing" development.

Here again fixing and washing are as usual, except that after fixation if a warm tone be desired and not previously obtained, the washing should be little more than a rinse, and the acid-iron-alum solution applied as before will greatly redden the color of the image while clearing the high lights.

All lantern slides should be varnished with a clear varnish, usually certain colorless gums dissolved in benzole.

To mount a lantern slide. Clean a thin, flawless glass plate 3¼ inches square; select and lay in position upon the *face* of the slide a suitable mask; on the mask lay the cleaned cover-glass. Wet a gummed "strip," which ought to be about ⅜ths of an inch wide and 14 inches long; lay one side of the now-protected slide in the middle and at one end of the wetted strip; turn the slide over side by side, always lifting with it

the sticky strip and always turning in the corners of the strip and running the fingers along back and front of the slide to make the strip adhere all along. On reaching the last corner, cut or tear off the extra bit of strip, and see that the strip adheres all along its length to the glasses. Lay the slide down face up as it is wished to appear on the screen, and then attach two white marks *one at each top corner;* these marks for a guide to the lanternist.

Transferotype prints when stripped on plain glass make fine slides; a strong point being that they may first be dried and then trimmed with scissors. They are then well soaked in water and stripped, see page 128.

CHAPTER XXIII.

USE OF THE OPTICAL LANTERN.

MANY lecturers and teachers are quite awake to the advantages that would arise from the use in lecture and class-rooms of the optical lantern, but almost all are deterred from the use of this valuable instrument by a mistaken idea as to the difficulties attending its use. The writer has conversed on this subject with several Professors of note, and in every case the difficulties were either imaginary or exaggerated.

It is admitted that under certain conditions the student will learn more of the nature of his subject by making a careful, even if faulty, drawing of it as seen in the microscope. But in very many cases the value of drawing is confined to the time actually employed upon the sketch; that is to say, that whatever is noticed at the time of sketching is learned, but nothing more; and the sketch thus executed can never teach anything more. A photo-micrograph not only reproduces details independent of the momentary observation of the operator, but it is a *litera scripta* which is itself open to further and more leisurely and careful examination, and, moreover, it will probably contain details beyond the power of the hand to copy, even if the eye noticed them; and if there is one method more apt than another to lead to fresh discoveries, it is the method of enlarging in the optical lantern.

So much for the student. The advantages of the lantern will be even more sensible to the teacher than the taught. The professor presumably knows what points he wishes to demonstrate, though by a sketch he may be unable to demonstrate them; and every one knows the uncertainty and inconvenience of demonstration to a class by one or more microscopes and oral explanations. But let a suitable photograph be produced, a lantern-slide made therefrom, and the image

nited, because the number of subjects suited to the instru- is limited. The loss of light in projecting a large image ven a moderately thick object is so considerable, that only xceptional cases can success be expected. Moreover, as optical science now stands, the combined difficulties of t magnification, illumination, resolution, and definition are great to be satisfactorily overcome, except in specially rable circumstances.*

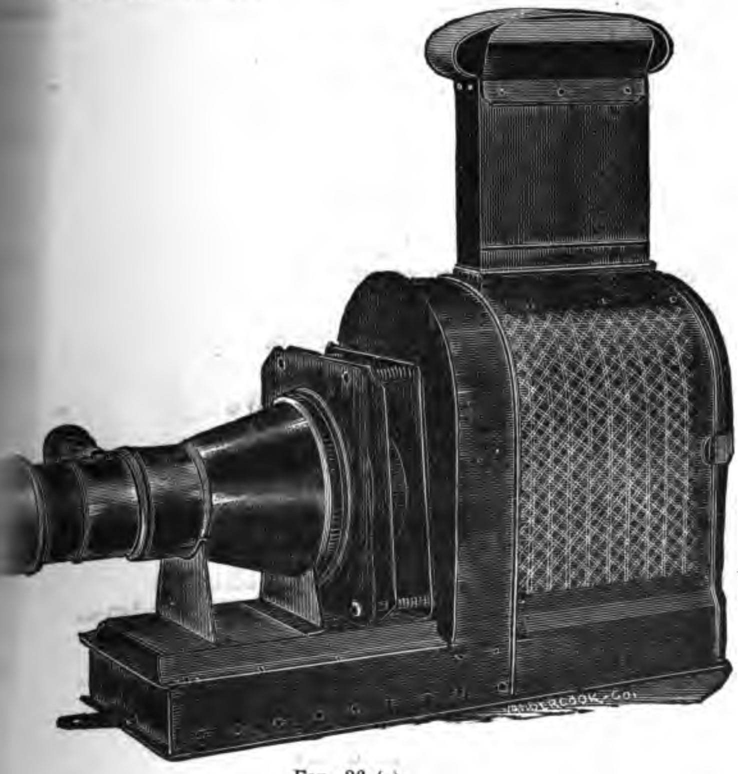


FIG. 36 (*a*).

The instrument known as an optical (or *vulgo* "magic") lantern is quite common and its appearance familiar to every

* Since this was written the author has seen a greatly improved instrument by the same makers and for the same purpose. It is, however, costly. It is shown in Fig. 36 in its latest and best form.

one. It is simply a box to hold the condenser, object or slide, and projecting lens in certain relations to each other and to the radiant, and to prevent the radiant from illuminating the screen directly. The screen is usually a sheet of white fabric, cloth or paper, but it ought to be, especially for purposes now under consideration, an opaque white surface, as plaster on a smooth wall. Paper with a smooth but not shiny surface, pasted to a wall or board of sufficient size, will answer every purpose. The diameter of the screen should be about one-third of the length of the lecture room; there is no necessity for much more, and in any case 15 to 18 feet will be the extreme likely in ordinary cases to be convenient.

An oil lamp made on scientific principles, due attention to draught being the main feature, will illuminate a ten-feet screen well, an eight-feet one perfectly. Number of wicks is of less consequence than the position of the wicks with relation to each other, and still more emphatically with relation to the condenser. A lantern full of burning wicks will give less light and worse confusion than one wick or three properly placed. A lantern known in America as the Scovill "Sciopticon" is as good as any oil lamp we know. We figure this article Fig. 36 (*a*).

Perhaps the condenser is the most important part of a lantern. It should be a double one certainly, and a triple is by some considered superior. A condenser which works very well with a wick lamp need not be the best for the lime-light, and the converse holds equally good. Still a condenser which gives an even, brilliant image, free from spherical aberration, with the lime light will suit well for an oil lamp with one or three wicks as usually arranged.

Now that oxygen is obtained in our countries so easily, of so good quality and at such moderate prices, we think it probable that a lecturer who has once used the lime-light would not long tolerate the nuisance of an oil lamp. There is perhaps no necessity for a serious nuisance in connection with oil; and whatever trouble there is will fall not on the lecturer so much as on paid assistants; none the less the inconveniences of lime-

light are so small compared with those of oil that we recommend the former in all cases where common house gas is attainable. For any ordinary class rooms the light produced by a "blow-through" blow-pipe on a "soft" lime will be found ample, either for projecting a photographic slide image on a 12 to 15 feet screen, or an image of the actual object—if suitable at all—or a screen of about 5 or 6 feet diameter, using in the latter case a microscopic objective, in the former a photographic lens of the portrait type. For our "blow-through" jet we require one tube of the jet to be connected with the gas supply of the building; the oxygen gas we keep in a steel cylinder under pressure, or in a bag between weighted pressure boards; these with a supply of lime cylinders are all the appliances required. There is no smell, no cleaning needed, no danger, nor any notable heat. There are several forms of blow-through, or as it is sometimes called, "safety" jet. The hydrogen issues and burns at the larger orifice, the oxygen is forced at some pressure through the hydrogen flame, a jet of the two gases burning impinges on the lime, which like other refractory substances gives a brilliant light in combustion. The area of incandescence with this jet is larger considerably than the area produced by the "mixing-jet," which gives a light both smaller and brighter. The "safety" jet is on the whole better adapted for the lecture-room than the mixing jet, not so much on the score of safety as on that of convenience. A mixing jet is shown in Fig. 11.

The objection usually raised in our hearing to the use of the lantern for classes is the difficulty of darkening the lecture-room. There need be no trouble on this point, though there may be some expense if the lectures are given in the daytime. Ordinary folding shutters, if decently fitted, will exclude light sufficiently, but in Britain we have a very good shutter for any purpose, probably the best for all purposes, called Clarke's Patent Shutter. It is made on the "Louvre" principle of strips of metal or wood, and on being raised it coils itself up into a receptacle above the window. These shutters can be pulled in a few seconds, and in the writer's house they shut out every beam of light that could mar the lantern image.

The axis of the lantern optical system may be horizontal, and the lantern may be raised so that this axis "produced" falls upon the centre of the screen; or the lantern may be placed on an ordinary table or stand tilted upwards; and the screen tilted the opposite way until it is perpendicular to the optical axis of the lantern.

The lantern slides are held in position in the lantern by a device known as a "carrier." The simpler this carrier is the better, provided that the slides can be easily and certainly centred. No carrier for our purpose is likely to excel the old "Chadwick," well known in England, at least; but one of the mechanically centering ones may be used.

The projection lens should have a focal length suitable to the size of disc required and the distance from lantern to screen.

S=Size of opening in slide in inches.

D=Diameter of disc in feet.

L=Distance of lantern from screen in feet.

F=Focal length of projection lens in inches.

$$L=\frac{D\times F}{S} \quad . \quad D=\frac{L\times S}{F} \quad . \quad F=\frac{L\times S}{D}$$

(From "The Magic Lantern Manual," by W. I. Chadwick. London: Warne & Co.)

A good light is obtained more by careful adjustment of the proportions of the gases than by heavy pressure. It is, of course, necessary to accurately centre the various parts of the optical system, and to get the radiant as nearly as may be in the exact focus of the condenser.

The limes should be always kept in a dry or air tight receptacle, and it is well to heat or even bake them for a short time before use.

If bag and pressure boards are used the latter must have a free fall, and no person should be allowed to touch the bag when the gas is alight. The weights must be of such shape, or so fixed, as to have no chance of falling off.

If any hitch should occur the oxygen is to be turned off first; on lighting up at first the hydrogen is always to be

lighted before the oxygen, and the full brilliance is to be got by turning on the gases alternately little by little. The "cut off" jet designed by the writer is specially recommended for the lecture room, gas and trouble are greatly economized by the simple contrivance (see page 44).

Oxygen and hydrogen, if desired, may very conveniently be stored in gas tanks or holders made of sheet iron. The gases may be used directly from such tanks. If bags are used for the two gases, each bag should be conspicuously marked "H" or "O," or the bags should be different in appearance. There is no necessity for an accident even if the gases should get mixed in one bag provided that the pressure be kept up; but risk, however slight, should be avoided. With the gas in cylinders there is no risk.

Postscript.—A learned professor has just suggested another difficulty to the writer. "You do not," says this experienced teacher, "know medical students in the dark!" The writer admits his inexperience, but would gladly run the risks of gases and students mixed.

CHAPTER XXIV.

IMMERSION, APOCHROMATICS, AND APERTURE. OCULARS.

THE two greatest improvements made in our optical appliances within a period of many years have been, first, the introduction of the "homogeneous immersion" system for objectives; and second, the use of a new glass, having different dispersive powers from glasses previously made. The result of the discovery of this new glass is that in the new apochromatic objectives we have a more complete correction for color than ever we had before; that is to say, the new lenses are corrected not only for two spectrum regions as formerly, but also for a third region.

The system of immersion is now so much a matter of ancient history that we need only point out the advantages now universally admitted to arise from the latter development of immersion, viz: Homogeneous or oil-immersion. Before the days of oil-immersion trouble arose from the fact that between the object and the objective two media of different refractive powers intervened, viz: Crown-glass (the cover-glass) and air—or water. When a substance was found having approximately the same refractive index as crown-glass, and when the objective was practically joined to the cover-glass by this substance, viz: an oil, it is easy to see how great a step was gained, provided always that the object was either in contact with the cover-glass, or in a medium nearly equal in refractive power, and in contact with the cover. More oblique rays passed from object to objective, the illumination was better, working distance greater, and in fact there was improvement in almost every respect. By the immersion system lenses can be produced of larger aperture

than the limit available with dry lenses, and the "fan" of diffraction rays is by immersion "closed up."

To narrate the causes and considerations that led to the adoption of numerical aperture as the basis of calculation of the apertures of objectives would be both tedious and out of place. We content ourselves, therefore, with saying that to Professor Abbe is due the system of calculation now almost universal, and by permission of the Royal Microscopical Society, we give in the latter part of this book a table of apertures, showing the relation between "N. A." and angular aperture, together with other matter of great value to the microscopist. It is important to remember that *resolution is proportional to numerical aperture but not to angular aperture.*

The maximum air angle being 1, we have oil immersion lenses with numerical aperture as high as 1.5, but nothing above 1.43 has, so far as we know, been made practically useful.

The immersion system is also used for condensers, and theoretically we ought to be able to use the whole aperture of the highest apertured glasses, but few, if any, glasses are sufficiently well corrected to stand utilization of their entire aperture. (See paper by Mr. E. M. Nelson in "English Mechanic," No. 1,234, Nov. 1888, for information on this subject.) Messrs. Powell and Leland make a fine apochromatic condenser N. A. 1.4. Zeiss constructs a similar article N. A. 1, while many opticians make non-achromatised oil-immersion condensers up to N. A. 1.4, or nearly so.

Apochromatic homogeneous immersion objectives of high N. A. are at present the acme of microscopical practical optics. But while resolving power increases with numerical aperture the quality called penetration decreases as resolving power increases. We have, however, tried to show in an earlier chapter that this "penetration" is a bogus quality, and, in fact, a defect though a deceptive one. Nevertheless there are occasions not a few when moderate sharpness on various planes is preferable to absolute sharpness on any one plane, and in such cases the utilized aperture of the lens may be easily cut down by stopping down the condenser to any desired extent

short of loss of definition and resolution. Definition and resolution as technical terms must not be confounded. Resolution consists in visibly separating close markings, definition consists in imaging distinctly small compact objects.

In order to obtain the full benefit of the series of apochromatic objectives made by Zeiss it is necessary to use in combination with these objectives the "compensating eye-pieces" made to go with them. In order to obviate the necessity for an ocular being specially made to suit each objective, Abbe and Zeiss have been bold enough to deliberately introduce in certain objectives certain aberrations which are corrected by the oculars.

For the projection of a real image, such as in photo-micrography we require, free from aberrations, and visually and chemically correct, Abbe has designed and Zeiss makes a series of "projection oculars." These are the oculars to which we have referred as being the best, if not the only good, oculars for photo-micrography.

In both the compensating and projection eye-pieces Zeiss follows the commendable system of marking the eye-pieces, not by arbitrary and meaningless letters, as "A," "B," or "C," but with a number indicating the amount to which the objective image is magnified by the ocular; but it is to be noted in calculating the magnification of an image produced by these oculars, that the figure on the ocular is accurate only for the precise tube length for which the ocular is designed. The No. 4 ocular is intended for the continental tube of 160 millimeters (about 7 inches); and at 160 mm. behind the posterior conjugate focus of the objective, the objective-image is magnified just four times by the No. 4 ocular; but if we are caused to alter the tube-length in order to obtain better "correction for the cover glass," the calculation no longer can be taken as accurate, as far as regards our total magnification.

The magnification given by a projection ocular and objective combined on a screen at a known distance from the ocular may, with convenience, but only in one case with absolute accuracy, be calculated by dividing the distance in mm. from ocular to screen, multiplied by the number on the ocular, by

the focal length in mm. of the objective. Example: With an objective of 3 mm. focus, a No. 3 projection eye-piece and a screen thirty inches from the shoulder of the ocular, we get a magnification of approximately 750 diameters, 30 inches = say, 750 millimeters.

$$\frac{750 \times 3 \text{ (ocular)}}{3 \quad \text{(focus of lens)}} = 750.$$

But this applies with only moderate accuracy when we have, for instance, racked our tube to 10½ inches in place of the 250 mm. (10 inches) for which the ocular and objective are intended. If, however, our tube length be really 250 mm. our magnification may be taken as almost exactly 750 diars. in the above given example, at least the writer has not been able on experiment to verify any inaccuracy in the figures given.

The future advance in photo-micrography—if there is to be any advance in the optical line—will depend upon apochromatic objectives and condensers, and the use of wide angles. It is vain to say that all the greatest discoveries have been made with low-angled glasses, though the statement may be perfectly true. Had higher angled glasses been used the discoveries would have been made all the sooner, and our high-angled glasses of to-day demonstrate with perfect ease even in unskilled hands what required years of study and the most skilled microscopists to certify in by-gone days. And further, the science of practical optics was, say twenty years ago, far behind where it is now, and the opticians of these days, in achieving high angles, probably introduced such errors of correction as made the glasses practically worthless. So the observers did well to use well corrected low-angled glasses rather than faulty high-angled ones, and their discoveries were made with low-angled glasses, *faute de mieux*. The writer is in the constant habit of examining numbers of objects of the most diverse kinds, he has at command high-angled and low-angled glasses, yet even for cursory examination of such subjects as pathological, physiological, bacteriological and diatomaceous objects, he invariably takes as if by instinct the widest angled glass he can find, of suitable

power. For photo-micrography, as a matter of course, he uses apochromatics, and always at the highest angle possible consistent with contrast between "tissue" and ground. No doubt the old experienced microscopist, accustomed to low-angled glasses, will be sceptical, and may even at first believe in the inferiority of the wide angles, especially if he use an imperfect system of illumination, but we have firm confidence that after a fair trial and a little perseverance and fight with prejudice, the newer glasses will prove victorious, even in the eyes of our fathers of microscopy. If, in any branch, "want of penetration" can be disastrous, surely that branch is the photo-micrographic; yet of all the conditions under which we insist on a wide-angle apochromatic objective, photo-micrography is the chief.

CHAPTER XXV.

CLASSIFICATION OF OBJECTS—HOW TO TREAT THEM.

While we can not attempt to give definite rules for the treatment, microscopic or photographic, of every object or class of objects that may come under the notice of the Photo-micrographer, still in our somewhat varied experience of various classes of objects we have noticed facts and formed opinions which may be of service to our Readers. In hope, at least, of such service being rendered we shall set down a few points noted in our actual work.

Insect preparations are almost always exceedingly difficult to photograph well. In the first place if the insects are of any size and are mounted in cells as they ought to be, and not flattened by pressure as they sometimes are, we have to deal with the optical "difficulty" of focusing at once various planes. To meet this trouble the lowest available "power" should be used, and stretch of camera substituted for eye-piecing as a means of getting magnification, and even this does not help us much. Making small negative images and enlarging them will probably not help matters in the least, in our experience "enlarging" has never been of any service in overcoming the difficulty to which we allude. In our own work the most marked successes in this line have been obtained by the use of an apochromatic lens of 70 millimetres, or about 3 inches facal length, and a camera stretch of from 5 to 7½ feet. The illumination in a case such as this is apt to be a puzzle, but the best plan is perhaps one suggested to the writer by Mr. E. M. Nelson; namely: to use as condenser the field-glass of a good "A" eye-piece, placed close behind the object, (*i. e.* between the object and the light), the convex surface of the field-glass being turned towards the light. Other

glasses may doubtless be used, but this is the one most likely to be within reach of every microscopist.

The other salient difficulty with insects is a photographic one and depends on color. Insects are frequently very dense yellow in color which may be overcome by use of color-correct plates with or without yellow illumination; but when in addition to a densely non-actinic body they have pellucid wings, antennæ or legs, the difficulty becomes very great indeed, and skilful is he who can surmount such a concatenation of difficulties. Again the worker must look to careful and intelligent use of color-correct plates and colored screens or light. Exposure must be full for the densest part of the object; development should be sharp and short, and as soon as details are out in the dense parts, the negative should be fixed and intensification resorted to. We have an idea, the outcome of some experiments, that for this class of work the hydroquinone developer with the caustic alkalies soda or potash is eminently suited. (See page 96.)

Pellucid Objects, such as some diatoms, present difficulties of their own which we must notice. The difficulty is partly in the optical, partly in the photographic department of our work. By lowering the angular aperture of our lens we may produce more visual contrast between the pellucid object and the ground on which we see it, but we at once lose definition and resolution. This holds good in the photographic as well as ocular branch. If we lower the force of our radiant-power we improve matters visually by taxing less the "accommodating" power of our eye, but the same step has no advantage in our photography, for lowering the light simply entails increased exposure. With objects of this pellucid nature our best plan is to cut down the angle of our condenser as much as we can without any loss of definition or resolution, (which is equivalent to using as much as necessary of our objective's available aperture *and no more*), keeping the exposure as short as is consistent with getting a black negative ground, using a thickly coated plate, an emulsion replete with silver haloid, and a slow system of development, preferably perhaps hydroquinone with sodic or potassic hydrate ("caustic" soda or

potash.) And though as a rule we consider intensification of negatives after fixing, by mercury or otherwise, an operation little commendable, we must confess that for this particular class of object it has frequently proved vastly useful to us. A fine sample of this class of subject is a "plate" split off, usually by accident in cleaning, a diatom.

Physio-and Pathological Preparations are easy, difficult, or impossible to reproduce well according to their cutting and mounting. Assuming that the points to be portrayed by photography are well seen by the eye, it is our business to overcome difficulties of staining; but difficulties of uneven mounting, bad sectioning and the like are beyond our control. We would protest here both for our own sake and for the sake of pathological and physiological science, against the mania, apparently spreading, for gossamer sections. Granted that there are cases where no instrument we have can cut a section too thin, it is none the less true that those cases are exceedingly rare. A section cut to show the more minute bacteria, or for histological purposes in general, can perhaps not be too thinly cut, but for ordinary physiological and pathological research, sections are often cut too thin to be of any real use; and they are most obnoxious to the photo-micrographer. On the other hand tissues imperfectly or improperly prepared for cutting cannot be cut thin enough for any useful purpose, and the mischief of thick cutting is made all the more apparent when staining that would be good for ordinary sections, is used on these "slabs" of tissue.*

Given, however, a good section of the class of subject now under notice, we ought to produce by photography a representation far beyond the best that manual dexterity can accomplish. The question resolves itself into one of color-correct photography with careful and skillful correction of the objective specially if the work be histological. If "cells" are to be shown in the characteristic state of health or disease, the optical adjustment of all apparatus must be perfect. Epithelial cells, for instance, may be horribly travestied by improper lens correction or false lighting. The lowest power should be used that will show the formation required to be

* There are those who maintain, with some reason, that a section can hardly be too thin, provided it is sufficiently stained.

shown. If a one inch o. g. has sufficient aperture to show muscle striation, it is folly to use a one-eighth o. g.; if magnification alone is wanted, *in such a case* we should decidedly recommend camera enlargement.

Isolated histological subjects are sometimes very difficult, the difficulties coming under various heads already touched in this chapter or about to be touched. We allude to such things as epithelium cells, red and white blood corpuscles, spermatozoa, etc., spread on a slide. These objects do not, as a rule, take kindly to stains, and they are not only more or less rounded but require considerable magnification to make their morphology visible. Here again we must look to color-correct photography to give us contrast, and to accurate correction objectives, both for the actinic focus, and by careful collar or tube adjustment. We usually meet the pale red or blue of such staining by the yellow screens and yellow-sensitive plates. Slow development carefully restrained is indicated, and sometimes intensification necessitated. As a sample of this class we may cite the task of reproducing ciliated epithelium cells, to show which well, cilia, nuclei, and protoplasm, is not easy.

The ease or difficulty of photographing cover glass preparations of *bacteria* depends chiefly on their staining. The stains most frequently used for such preparations are either violet (gentian) or red (fuchsine). Few things are more difficult to photograph than a microbe lightly stained with gentian violet, or very lightly with fuchsine. If the stain in either case be pale, the only hopeful method is to use yellow screens and color-correct plates, no more angle than necessary being brought into play. Some organisms badly stained with Bismarck brown have completely baffled all our attempts to photograph them. In the case of pale pink staining, sometimes the result of faded or abortive fuchsine or eosine staining, the signal green glass screen has more than once helped us, but in most cases the yellow screen, theory to the contrary, has proved more useful. If organisms are well stained, the colors vigorous, the ground clear, the material evenly and thinly spread, the difficulties of this class of works are great

only because of the magnification required. We have succeeded well in such work with a cheap "student's" oil immersion one-twelfth by Swift, and also with a similar one-twentieth by Reichert, using no ocular in either case; it is within our knowledge that glasses by Powell and Lealand (specially a twenty-fifth), Beck, and Seibert have been successfully used in this manner and for the same purpose. The demonstration by photography of flagella, with which some micro-organisms are endowed, depends upon most accurate correction of objective coupled with suitable mounting and staining. Though many of these organisms are flagellated, it is a most difficult matter to keep the flagella visible in mounting, and it is little less difficult to photograph them when visible.

Test diatoms present the usual microscopic difficulties with, generally, a photographic one "thrown in," viz., the difficulty of getting contrast. In these cases angle must not be dispensed with, for the great point is not only to get resolution, but to get very strong and distinct resolution. The photographic difficulties must be overcome by photographic skill and not by sacrifice of optical excellence. The diatoms should be absolutely in contact with the cover glass, to determine which Beck's "Vertical Illuminator" is invaluable, and the medium in which the objects are mounted should be of suitable refractivity.

It seems to be the fate of every photo-micrographer of any ambition, sooner or later, to attempt to photograph "*amphipleura pellucida* in lines." The first thing is to get a frustule as coarsely marked as possible, but withal clean and flat, mounted in a medium of high refraction index. The "striæ" seem usually to run about 95,000 to the inch. The lines cannot with any angular aperture open to us be clearly shown by axial illumination, and oblique illumination is attained by putting into the condenser a disc with a slot of one or other of the following shapes: *B* being preferable in most cases. This slot is variable in breadth and length, and must be chosen to give the best result by experiment. A strong light should be used, as lime light, for under the best conditions of illumination

the exposure will be protracted. During the long exposure there is great risk of motion of the apparatus not only from tremor of the apartment, but from heat of the radiant affecting the apparatus. An alum trough is therefore recommended between light and condenser.

FIG. 37.

If the edge of a lamp-flame or the face of a lime cylinder is used as the illuminating surface, the frustule must be arranged vertically on the stage, and the slot of the condenser stop is to run parallel to the frustule. The directions of valve and light are therefore shown thus: Fig. 38, while in the field of

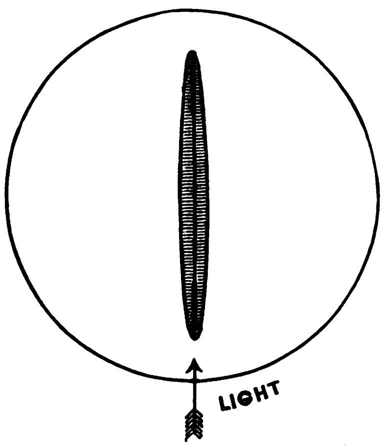


FIG. 38.

the microscope almost the whole will be dark, except the frustule itself, until the high power o. g. is brought into play.

The successive operations towards "setting up" this object may be thus described. A suitable frustule is chosen, a medium power objective being used to centre the object and the light, and to focus the condenser accurately upon the object. The slotted stop is then inserted in the condenser, and the effect examined with the medium power; little else beside the frustule should be illuminated. Both high-power objective and condenser must be oil immersions and of the best quality.

The high-power objective is now put into place and action, and the most accurate correction by collar or tube length obtained by experiment. The condenser will almost certainly require re-focusing after the high-power glass is brought into play. With perfection of apparatus the white lines ought to appear about four times as broad as the black ones (Nelson).

The focusing of the image on the screen is with ordinary achromatic lenses exceedingly difficult, with apochromatics less so. No pains should be spared to get a correct focus, and after it is got the whole apparatus should be allowed to rest for ten minutes at least, the light at full blaze; after this time the image is to be again examined to test for steadiness. Clearly if the accuracy is lost in ten minutes it is hopeless to attempt an exposure of twenty minutes to an hour with lime, not to speak of four to ten hours with an oil lamp. We have exposed for six hours on this diatom with oil, and our usual time with lime is twenty-five to thirty minutes; with these exposures we expect to get a good photographic negative; if there has been no motion of the image we are much pleased and somewhat surprised. There is no special difficulty in development.

In spite of all these details, *A. pellucida* is child's play to photograph in comparison with such tests as *P. angulatum*, *S. gemma*, and *N. rhomboides* by axial light and to show "black dots." *P. angulatum* in white areoles, or *N. rhomboides* in squares with a special disc in the condenser, is infinitely easier than the same in black dots.

CHAPTER XXVI.

BLACK BACKGROUNDS. OPAQUE MOUNTS. POLARIZED OBJECTS.

PHOTOGRAPHY of certain lustrous objects upon a dark ground is not merely, as some think, a playful way of producing a sensational picture, but is in many cases a really useful method of depicting suitable objects. We have seen a lecture on Diatom Structure illustrated almost entirely by lantern-slides of diatoms on black ground; many crystals, and certain eyes are better seen on such a ground than on a white one.

When objects are "mounted opaque" they require to be photographed by reflected light, and the background is then naturally dark, but when objects are mounted in the common way on clear glass, we require for a black ground one or other of several optical instruments. First we mention a "spot lens," which, before it became obsolete, was used below the stage, but is now entirely replaced by a "paraboloid," or, better, by the addition of certain disc-stops to an ordinary substage condenser. The paraboloid is a very pretty piece of optical ingenuity, sometimes called "parabolic illuminator," but in practice the condenser with stops will be found superior.

For this class of work the achromatic substage condenser is usually furnished with a set of the discs figured No. 5, and there is in the fittings of the condenser a slot or other receptacle to receive the stops. With powers higher than a quarter-inch it will be found somewhat difficult to work the system properly, still it is not impossible to obtain good results even with immersion glasses. The practice is somewhat as follows: The condenser is centred, the condenser and objective focused as usual on the object, but in the present work a bull's eye may without detriment, and even with advantage, be used to

parallelize the rays on the back of the condenser. Now one or other of the black discs is placed in the condenser, which may be racked up and down so that the best image of the object and the blackest ground possible are attained. The point of chief importance is to get the margins of the object perfectly sharp against the black ground, and the secret of success is to use the smallest disc that will give a brilliantly-lighted object with an absolutely black ground. The "spot lens" may aptly be likened to the above arrangement minus the power of altering the size of the spot, and the parabolic illuminator may take a place midway between the two, for it has a certain range of adaptation in virtue of a small movable "spot" worked from its lower end. We need hardly say that in this work a prolonged exposure is required, more prolonged than might be expected by the beginner.

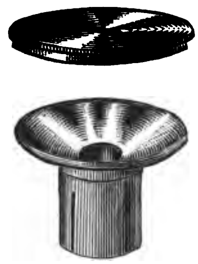


FIG. 39.—LIEBERKUHN. (BECK.)

FIG. 40.—WENHAM'S PARABOLIC ILLUMINATOR.

On the whole, we should prefer a spot lens to a paraboloid, were we compelled to use one or other.

When an opaque mount has to be photographed we should use the Lieberkuhn (Fig. 39) when it is available. With the Lieberkuhn the light passes from the radiant round the object to the Lieberkuhn (which is fixed to the objective) and thence reflected back upon the object, which is thereby illuminated evenly from all sides. This necessitates an object mounted on a black disc having a clear space all round it.

As the province of the Lieberkuhn is to reflect and *focus* the rays upon the object, it will be easily understood that the Lieberkuhn has to be made to correspond with a lens of a par-

ticular focus, so that in practice a Lieberkuhn is required for each objective used with it.

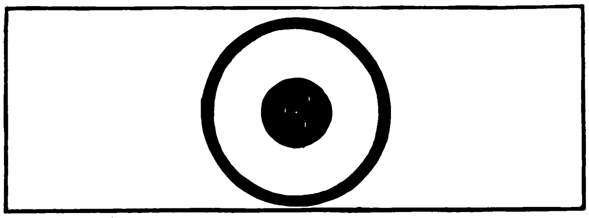


FIG. 41.—MOUNT FOR LIEBERKUHN.

Failing a Lieberkuhn for opaque-mounted objects, we may have recourse to any other system of condensing rays of light upon our object. Thus the light may be thrown upon the

FIG. 42.—SIDE REFLECTOR. (SWIFT.)

object through a bull's eye, which should be placed at an angle as narrow as possible to the plane of the object, *i. e.*, as near as possible to the microscope tube.

Or an article variously known as a "parabolic reflector," a "side reflector," or a "cup," may be used in conjunction with a bull's eye. The action of the cup may easily be gathered from our cut, Fig. 42. A parallelizing glass will be useful here also, and the radiant is to be placed on a line perpendicular to the optic axis of the microscope.

Polarising apparatus in connection with photo-micrography is often of great value, in the investigation of crystals and crystalline matters. The worker in this line must be prepared for considerable difficulties in color-rendering, but beautiful and useful results have been achieved by some. It is important to use prisms as large as possible, to consider carefully the selenite to be used, and to study the best effects in color-rendering that can be produced by modern photography.

Books, etc. Referred to or Consulted.

BEALE, DR. LIONEL S., F.R.S. "How to Work with the Microscope." Harrison: London. Lindsay & Blakiston: Philadelphia.

BOUSFIELD, E. C., L.R.C.P. "Guide to Photo-Micrography." London: Kent & Co.

CARPENTER, DR. W. B., F.R.S. "The Microscope and its Revelations." London: Churchill.

CROOKSHANK, EDGAR M. M.B. "Photography of Bacteria." London: H. K. Lewis.

JENNINGS, I. H. "Photo-Micrography." London: Piper & Carter.

KOCH, DR. R. "On the Investigation of Pathogenic Organisms." Translation in "Microparasites in Disease," by Victor Horsley, B.Sc., from "Mittheilungen aus dem Kaiserlichen Gesundheitsamte," Vol. 1. Berlin. London: New Sydenham Society.

MADDOX, R. L., M.D.; Hon. F.R.M.S. "Papers in *British Journal of Photography*," *passim*, and elsewhere.

NAEGELI, PROF. CARL, and SCHWENDENER, PROF. S. "The Microscope in Theory and Practice." London: Swan, Sonnenschein & Co.

NELSON, EDWARD M. "Papers in English Mechanic," *passim*.

STERNBERG, MIQUEL, TRUAN, DE WITT—and others.

JOURNAL OF ROYAL MICROSCOPICAL SOCIETY, *passim*, London.

FRAENKEL and PFEIFFER. "*Atlas der Bakterienkunde*," Berlin, 1889.

ABNEY, CAPT. W. DE W., R.E., F.R.S. "Treatise on Photography." London: Longmans, Green & Co.

BOTHAMLEY, C. H. Papers before Photo Convention, 1887, 1888, 1889, "*Journal of Chemical Industry*"; also "*Photo News*," *passim*.

BURTON, PROF. W. K. "Practical Guide to Photographic Printing," etc. London: Marion & Co.

BURTON, W. K., and PRINGLE, ANDREW. "Processes of Pure Photography." New York: The Scovill & Adams Co.

HARDWICH, T. F., and TAYLOR, J. T. "Photographic Chemistry." New York: The Scovill & Adams Co.

TABLE FOR ENLARGEMENT AND REDUCTION

COMPUTED FOR CENTIMETERS OR INCHES.

Equivalent Focus of the Lens.	Distances of the Object and the Ground Glass Screen from the Center of the Objective.																								
	1 t.	2 t.	3 t.	4 t.	5 t.	6 t.	7 t.	8 t.	9 t.	10 t.	11 t.	12 t.	13 t.	14 t.	15 t.	16 t.	17 t.	18 t.	19 t.	20 t.	21 t.	22 t.	23 t.	24 t.	25 t.
5..	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
	10	7.5	6.7	6.2	6	5.8	5.7	5.6	5.6	5.5	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2
6..	12	18	24	30	36	42	48	54	60	66	72	78	84	90	92	102	108	114	120	126	132	138	144	150	156
	12	9	8	7.5	7.2	7	6.9	6.8	6.7	6.6	6.5	6.5	6.4	6.4	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.2
7..	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147	154	161	168	175	182
	14	10.5	9.3	8.8	8.4	8.2	8	7.9	7.8	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.4	7.4	7.4	7.3	7.3	7.3	7.3	7.3
8..	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	200	208
	16	12	10.7	10	9.6	9.3	9.1	9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.5	8.4	8.4	8.4	8.4	8.4	8.3	8.3	8.3
9..	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	225	234
	18	13.5	12	11.3	10.8	10.5	10.3	10.1	9.9	9.9	9.8	9.8	9.7	9.6	9.6	9.6	9.5	9.5	9.5	9.5	9.4	9.4	9.4	9.4	9.4
10..	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260
	20	15	13.3	12.5	12	11.7	11.4	11.3	11.1	11	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.6	10.5	10.5	10.5	10.5	10.4	10.4	10.4
11..	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176	187	198	209	220	231	242	253	264	275	286
	22	16.5	14.7	13.8	13.2	12.8	12.6	12.4	12.2	12.1	12	11.9	11.8	11.8	11.7	11.7	11.6	11.6	11.6	11.6	11.5	11.5	11.5	11.5	11.4
12..	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312
	24	18	16	15	14.4	14	13.7	13.5	13.3	13.2	13.1	13	12.9	12.9	12.8	12.7	12.7	12.7	12.6	12.6	12.6	12.5	12.5	12.5	12.5
13..	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260	273	286	299	312	325	338
	26	19.5	17.3	16.3	15.6	15.1	14.9	14.6	14.4	14.3	14.2	14.1	14	13.9	13.9	13.8	13.8	13.7	13.7	13.7	13.6	13.6	13.6	13.5	13.5
14..	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308	322	336	350	364
	28	21	18.7	17.5	16.8	16.3	16	15.8	15.6	15.4	15.3	15.2	15.1	15	14.9	14.9	14.8	14.8	14.7	14.7	14.7	14.6	14.6	14.6	14.6
15..	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390
	30	22.5	20	18.8	18	17.5	17.1	16.9	16.7	16.5	16.4	16.3	16.2	16.1	16	15.9	15.9	15.8	15.8	15.8	15.7	15.7	15.7	15.6	15.6

16..	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320	336	352	368	384	400	416
	32	24	21.3	20	19.2	18.7	18.3	18	17.8	17.6	17.5	17.3	17.2	17.1	17.1	16.9	16.9	16.9	16.8	16.8	16.8	16.7	16.7	16.7	16.6
17..	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340	357	374	391	408	425	442
	34	25.5	22.7	21.3	20.4	19.8	19.4	19.1	18.9	18.7	18.5	18.4	18.3	18.2	18.1	18.1	18	17.9	17.9	17.9	17.8	17.8	17.7	17.7	17.7
18..	36	54	72	90	108	126	144	162	180	198	216	234	252	270	288	306	324	342	360	378	396	414	432	450	468
	36	27	24	22.5	21.6	21	20.6	20.3	20	19.8	19.6	19.5	19.4	19.3	19.2	19.1	19.1	19	18.9	18.9	18.8	18.8	18.8	18.8	18.7
19..	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361	380	399	418	437	456	475	494
	38	28.5	25.3	23.8	22.8	22.2	21.7	21.4	21.1	20.9	20.7	20.6	20.5	20.4	20.3	20.2	20.1	20.1	20	20	19.9	19.8	19.8	19.8	19.8
20..	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520
	40	30	26.6	25	24	23.3	22.9	22.5	22.2	22	21.8	21.7	21.5	21.4	21.3	21.3	21.2	21.2	21.1	21	21	20.9	20.9	20.8	20.8
21..	42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420	441	462	483	504	525	546
	42	31.5	28	26.3	25.2	24.5	24	23.7	23.3	23.1	22.9	22.8	22.6	22.5	22.4	22.3	22.2	22.2	22.1	22.1	22	21.9	21.9	21.9	21.8
22..	44	66	88	110	132	154	176	198	220	242	264	286	308	330	352	374	396	418	440	462	484	506	528	550	572
	44	33	29.3	27.5	26.4	25.7	25.1	24.8	24.4	24.2	24	23.8	23.7	23.6	23.5	23.4	23.3	23.2	23.2	23.1	23	23	23	22.9	22.1
23..	46	69	92	115	138	161	184	207	230	253	276	299	322	345	368	391	414	437	460	483	506	529	552	575	598
	46	34.5	30.7	28.8	27.6	26.7	26.3	25.9	25.6	25.3	25.1	24.9	24.8	24.6	24.5	24.4	24.3	24.3	24.2	24.2	24.1	24	24	24	23.9
24..	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600	624
	48	36	32	30	28.8	28	27.4	27	26.7	26.4	26.2	26	25.8	25.7	25.6	25.5	25.4	25.3	25.3	25.2	25.1	25.1	25	25	25
25..	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650
	50	37.5	33.3	31.3	30	29.2	28.6	28.1	27.8	27.5	27.3	27.1	26.9	26.8	26.7	26.6	26.5	26.4	26.3	26.3	26.2	26.1	26.1	26	26

The use of the above table will best be explained by illustrations:

To enlarge six times with a lens of 15 centimeters (or inches) focal length. We find in the table under 6 *t.* and opposite the figures $\frac{105}{17.5}$, hence the object must be 17.5, and the screen 105 centimeters (or inches) from the centre of the lens.

To reduce eight times with a lens of 19 centimeters (or inches) focus, the object must be 171 and the screen 21.4 centimeters (or inches) from centre of lens.

The table can be formulated thus: Where p = focal length of lens, a = distance from ground-glass to centre of lens and b = distance from object to centre of lens, then $\frac{1}{a} + \frac{1}{b} = \frac{1}{p}$

APERTURE TABLE.

By special permission of the Royal Microscopical Society.

Numerical Aperture. ($n \sin u = a$.)	Corresponding Angle ($2u$) for Air ($n = 1·00$).	Water ($n = 1·33$).	Homogeneous Immersion ($n = 1·52$).	Limit of Resolving Power, in Lines to an Inch. White Light. ($\lambda = 0·5269\ \mu$, Line E.)	Monochromatic (Blue) Light. ($\lambda = 0·4861\ \mu$, Line F.)	Photography. ($\lambda = 0·4000\ \mu$, near Line h).	Illuminating Power. (a^2.)	Penetrating Power. $\left(\frac{1}{a}\right)$
1·52	..	..	180° 0′	146,543	158,845	193,037	2·310	·658
1·51	..	..	166° 51′	145,579	157,800	191,767	2·280	·662
1·50	..	..	161° 23′	144,615	156,755	190,497	2·250	·667
1·49	..	..	157° 12′	143,651	155,710	189,227	2·220	·671
1·48	..	..	153° 39′	142,687	154,665	187,957	2·190	·676
1·47	..	..	150° 32′	141,723	153,620	186,687	2·161	·680
1·46	..	..	147° 42′	140,759	152,575	185,417	2·132	·685
1·45	..	..	145° 6′	139,795	151,530	184,147	2·103	·690
1·44	..	..	142° 39′	138,830	150,485	182,877	2·074	·694
1·43	..	..	140° 22′	137,866	149,440	181,607	2·045	·699
1·42	..	..	138° 12′	136,902	148,395	180,337	2·016	·704
1·41	..	..	136° 8′	135,938	147,350	179,067	1·988	·709
1·40	..	..	134° 10′	134,974	146,305	177,797	1·960	·714
1·39	..	..	132° 16′	134,010	145,260	176,527	1·932	·719
1·38	..	..	130° 26′	133,046	144,215	175,257	1·904	·725
1·37	..	..	128° 40′	132,082	143,170	173,987	1·877	·739
1·36	..	..	126° 58′	131,118	142,125	172,717	1·850	·735
1·35	..	..	125° 18′	130,154	141,080	171,447	1·823	·746
1·34	..	..	123° 40′	129,189	140,035	170,177	1·796	·741
1·33	..	180° 0′	122° 6′	128,225	138,989	168,907	1·769	·752
1·32	..	165° 56′	120° 33′	127,261	137,944	167,637	1·742	·758
1·31	..	160° 6′	119° 3′	126,297	136,899	166,367	1·716	·763
1·30	..	155° 38′	117° 35′	125,333	135,854	165,097	1·690	·769
1·29	..	151° 50′	116° 8′	124,369	134,809	163,827	1·664	·775
1·28	..	148° 42′	114° 44′	123,405	133,764	162,557	1·638	·781
1·27	..	145° 27′	113° 21′	122,441	132,719	161,287	1·613	·787
1·26	..	142° 39′	111° 59′	121,477	131,674	160,017	1·588	·794
1·25	..	140° 3′	110° 39′	120,513	130,629	158,747	1·563	·800
1·24	..	137° 36′	109° 20′	119,548	129,584	157,477	1·538	·806
1·23	..	135° 17′	108° 2′	118,584	128,539	156,207	1·513	·813
1·22	..	133° 4′	106° 45′	117,620	127,494	154,937	1·488	·820
1·21	..	130° 57′	105° 30′	116,656	126,449	153,668	1·464	·826
1·20	..	128° 55′	104° 15′	115,692	125,404	152,397	1·440	·833
1·19	..	126° 58′	103° 2′	114,728	124,359	151,128	1·416	·840
1·18	..	125° 3′	101° 50′	113,764	123,314	149,857	1·392	·847
1·17	..	123° 13′	100° 38′	112,799	122,269	148,588	1·369	·855
1·16	..	121° 26′	99° 29′	111,835	121,224	147,317	1·346	·862
1·15	..	119° 41′	98° 20′	110,872	120,179	146,048	1·323	·870
1·14	..	118° 0′	97° 11′	109,907	119,134	144,777	1·300	·877
1·13	..	116° 20′	96° 2′	108,943	118,089	143,508	1·277	·885
1·12	..	114° 44′	94° 55′	107,979	117,044	142,237	1·254	·893
1·11	..	113° 9′	93° 47′	107,015	115,999	140,968	1·232	·901
1·10	..	111° 36′	92° 43′	106,051	114,954	139,698	1·210	·909
1·09	..	110° 5′	91° 38′	105,087	113,909	138,428	1·188	·917
1·08	..	108° 36′	90° 34′	104,123	112,864	137,158	1·166	·926
1·07	..	107° 8′	89° 30′	103,159	111,819	135,888	1·145	·935
1·06	..	105° 42′	88° 27′	102,195	110,774	134,618	1·124	·943
1·05	..	104° 16′	87° 24′	101,231	109,727	133,348	1·103	·952
1·04	..	102° 53′	86° 21′	100,266	108,684	132,078	1·082	·962
1·03	..	101° 30′	85° 19′	99,302	107,639	130,808	1·061	·971
1·02	..	100° 10′	84° 18′	98,338	106,593	129,538	1·040	·980
1·01	..	98° 50′	83° 17′	97,374	105,548	128,268	1·020	·990
1·00	180° 0′	97° 31′	82° 17′	96,410	104,503	126,998	1·000	1·000
0·99	163° 48′	96° 12′	81° 17′	95,446	103,458	125,728	·980	1·010
0·98	157° 2′	94° 56′	80° 17′	94,482	102,413	124,458	·960	1·020
0·97	151° 52′	93° 40′	79° 18′	93,518	101,368	123,188	·941	1·031
0·96	147° 29′	92° 24′	78° 20′	92,554	100,323	121,918	·922	1·042
0·95	143° 36′	91° 10′	77° 22′	91,590	99,278	120,648	·903	1·053
0·94	140° 6′	89° 56′	76° 24′	90,625	98,233	119,378	·884	1·064
0·93	136° 52′	88° 44′	75° 27′	89,661	97,188	118,108	·865	1·075
0·92	133° 51′	87° 32′	74° 30′	88,697	96,143	116,838	·846	1·087
0·91	131° 0′	86° 20′	73° 33′	87,733	95,098	115,568	·828	1·099
0·90	128° 19′	85° 10′	72° 36′	86,769	94,053	114,298	·810	1·111
0·89	125° 45′	84° 0′	71° 40′	85,805	93,008	113,028	·792	1·124
0·88	123° 17′	82° 51′	70° 44′	84,841	91,963	111,758	·774	1·136

APERTURE TABLE.—*Continued.*

Numerical Aperture. (n sin u = a).	Corresponding Angle ($2u$) for			Limit of Resolving Power, in Lines to an Inch.			Illuminating Power (a^2).	Penetrating Power, $\left(\frac{1}{a}\right)$
	Air (n = 1·00).	*Water* (n = 1·33).	*Homogeneous Immersion* (n = 1·52).	White Light (λ = 0·5269 μ, Line E).	Monochromatic (Blue) Light (λ = 0·4861 μ, Line F).	Photography (λ = 0·4000 μ, near Line h).		
0·87	120° 55′	81° 42′	69° 49′	83,877	90,918	110,488	·757	1·149
0·86	118° 38′	80° 34′	68° 54′	82,913	89,873	109,218	·740	1·163
0·85	116° 25′	79° 37′	68° 0′	81,949	88,828	107,948	·723	1·176
0·84	114° 17′	78° 20′	67° 6′	80,984	87,783	106,678	·706	1·190
0·83	112° 12′	77° 14′	66° 12′	80,020	86,738	105,408	·689	1·205
0·82	110° 10′	76° 8′	65° 18′	79,056	85,693	104,138	·672	1·220
0·81	108° 10′	75° 3′	64° 24′	78,092	84,648	102,868	·656	1·235
0·80	106° 16′	73° 58′	63° 31′	77,128	83,603	101,598	·640	1·250
0·79	104° 22′	72° 53′	62° 38′	76,164	82,558	100,328	·624	1·266
0·78	102° 31′	71° 49′	61° 45′	75,200	81,513	99,058	·608	1·282
0·77	100° 42′	70° 45′	60° 52′	74,236	80,468	97,788	·593	1·299
0·76	98° 56′	69° 42′	60° 0′	73,272	79,423	96,518	·578	1·316
0·75	97° 11′	68° 40′	59° 8′	72,308	78,378	95,248	·563	1·333
0·74	95° 28′	67° 37′	58° 16′	71,343	77,333	93,979	·548	1·351
0·73	93° 46′	66° 34′	57° 24′	70,379	76,288	92,709	·533	1·370
0·72	92° 6′	65° 32′	56° 32′	69,415	75,242	91,439	·518	1·389
0·71	90° 28′	64° 32′	55° 41′	68,451	74,197	90,169	·504	1·408
0·70	88° 51′	63° 31′	54° 50′	67,487	73,152	88,899	·490	1·429
0·69	87° 16′	62° 30′	53° 59′	66,523	72,107	87,629	·476	1·449
0·68	85° 41′	61° 30′	53° 9′	65,559	71,062	86,359	·462	1·471
0·67	84° 8′	60° 30′	52° 18′	64,595	70,017	85,089	·449	1·493
0·66	82° 36′	59° 30′	51° 28′	63,631	68,972	83,819	·436	1·515
0·65	81° 6′	58° 30′	50° 38′	62,667	67,927	82,549	·423	1·538
0·64	79° 36′	57° 31′	49° 48′	61,702	66,882	81,279	·410	1·562
0·63	78° 6′	56° 32′	48° 58′	60,738	65,837	80,009	·397	1·587
0·62	76° 38′	55° 34′	48° 9′	59,774	64,792	78,739	·384	1·613
0·61	75° 10′	54° 36′	47° 19′	58,810	63,747	77,469	·372	1·639
0·60	73° 44′	53° 38′	46° 30′	57,846	62,702	76,199	·360	1·667
0·59	72° 18′	52° 40′	45° 40′	56,881	61,657	74,929	·348	1·695
0·58	70° 54′	51° 42′	44° 51′	55,918	60,612	73,659	·336	1·724
0·57	69° 30′	50° 45′	44° 2′	54,954	59,567	72,389	·325	1·754
0·56	68° 6′	49° 48′	43° 14′	53,990	58,522	71,119	·314	1·786
0·55	66° 44′	49° 51′	42° 25′	53,026	57,477	69,849	·303	1·818
0·54	65° 22′	47° 54′	41° 37′	52,061	56,432	68,579	·292	1·852
0·53	64° 0′	46° 58′	40° 48′	51,097	55,387	67,309	·281	1·887
0·52	62° 40′	46° 2′	40° 0′	50,133	54,342	66,039	·270	1·923
0·51	61° 20′	45° 6′	39° 12′	49,169	53,297	64,769	·260	1.961
0·50	60° 0′	44° 10′	38° 24′	48,205	52,252	63,499	·250	2·000
0·48	57° 22′	42° 18′	36° 49′	46,277	50,162	60,959	·230	2·083
0·46	54° 47′	40° 28′	35° 15′	44,349	48,072	58,419	·212	2·174
0·45	53° 30′	39° 33′	34° 27′	43,385	47,026	57,149	·203	2·222
0·44	52° 13′	38° 38′	33° 40′	42,420	45,981	55.879	·194	2·273
0·42	49° 40′	36° 49′	32° 5′	40,492	43,891	53,339	·176	2·381
0·40	47° 9′	35° 0′	30° 31′	38,564	41,801	50,799	·160	2·500
0·38	44° 40′	33° 12′	28° 57′	36,636	39,711	48,259	·144	2·632
0·36	42° 12′	31° 24′	27° 24′	34,708	37,621	45,719	·130	2·778
0·35	40° 58′	30° 30′	26° 38′	33,744	36,576	44,449	·123	2·857
0·34	39° 44′	29° 37′	25° 51′	32,779	35,531	43,179	·116	2·911
0·32	37° 20′	27° 51′	24° 18′	30,851	33,441	40,639	·102	3·125
0·30	34° 56′	26° 4′	22° 46′	28,923	31,351	38,099	·090	3·333
0·28	32° 32′	24° 18′	21° 14′	26,995	29,261	35,559	·078	3·571
0·26	30° 10′	22° 33′	19° 42′	25,067	27,171	33,019	·068	3·846
0·25	28° 58′	21° 40′	18° 56′	24.103	26,126	31,749	·063	4·000
0·24	27° 46′	20° 48′	18° 10′	23,138	25,081	30,479	·058	4·167
0·22	25° 26′	19° 2′	16° 38′	21,210	22,991	27,940	·048	4·545
0·20	23° 4′	17° 18′	15° 7′	19.282	20,901	25,400	·040	5·000
0·18	20° 44′	15° 34′	13° 36′	17,354	18,811	22.860	·032	5·555
0·16	18° 24′	13° 50′	12° 5′	15,426	16,721	20.320	·026	6·250
0.15	17° 14′	12° 58′	11° 19′	14,462	15,676	19,050	·023	6·667
0·14	16° 5′	12° 6′	10° 34′	13,498	14,630	17,780	·020	7·143
0·12	13° 47′	10° 22′	9° 4′	11,570	12,540	15,240	·014	8·333
0.10	11° 29′	8° 38′	7° 34′	9,641	10,450	12,700	·010	10·000
0·08	9° 11′	6° 54′	6° 3′	7,713	8,360	10,160	·006	12·500
0·06	6° 53′	5° 10′	4° 32′	5,785	6,270	7,620	·004	16·667
0·05	5° 44′	4° 18′	3° 46′	4,821	5,225	6,350	·003	20·000

INDEX.

Description of Plates after Contents.
FRONTISPIECE—

THE MERCER

Photo-Micrographic

CAMERA.

Size, 2¾x3¼. Price, $7.50.

Mercer Camera, shown with Microscope to illustrate working.

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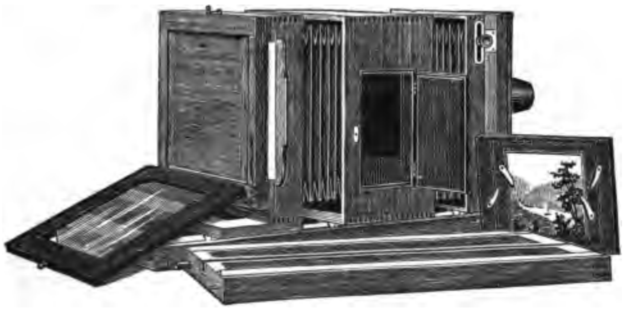

It is made in two forms: the cheaper, No. 1, (selling for $18.00) is adapted only to the making of negatives on plates 3¼x4¼, or 4¼x5½, as may be necessary. The complete form No. 2 (costing $30) is also a miniature enlarging, reducing, and copying camera, admirably adapted to the production of lantern transparancies from any size negative up to 4¼x5½.

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The bellows have an extension ot two feet in addition to the length of the box, sliding very smoothly upon V-shaped ways, which for greater convenience are made in two sections, firmly attached to each other by wooden dowels, and a solid brass screw, worked by a milled head.

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